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MILITARY AIRBORNE SEGMENT (MAS) SPECIFICATION

For

Joint Precision Approach and Landing System (JPALS) Local Area Differential Global Positioning System (LDGPS)

Revision 1.0

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Electronic Systems Center

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1 Scope

1.1 Identification

This Specification establishes the requirements for the Military Airborne Segment (MAS) of the Joint Precision Approach and Landing System (JPALS), Local Differential Global Positioning System (LDGPS). These requirements were derived from the System Requirements Document (SRD) [28] for the JPALS Common Program. Shipboard requirements contained in the JPALS Operational Requirements Document (ORD) [15] are contained in a separate airborne specification, hence the use of the term JPALS herein refers to the system level implementation of LDGPS only.

1.2 System Overview

JPALS provides the Department of Defense (DoD) with a precision approach and landing capability for Fixed Base, Tactical, and Special Mission Operations. JPALS can also provide terminal area operations including missed approach guidance and potentially other applications.

The GPS positioning service currently provided is insufficient to meet the integrity, continuity, accuracy, and availability demands of precision approach and landing navigation. JPALS applies LDGPS techniques to augment the GPS positioning service in order to meet these demands.

JPALS is modeled on the Federal Aviation Administration (FAA) Local Area Augmentation System (LAAS). This is done for two main reasons. First, because LAAS, like JPALS, is an LDGPS based precision approach landing system. Second, because compatibility with the LAAS Ground Facility (LGF) an FAA implementation of the International Civil Aviation Organization (ICAO) Ground Based Augmentation System (GBAS), is required to ensure JPALS civil interoperability.

JPALS differs from LAAS in three major aspects. First, JPALS must support military operations world-wide and, consequently, is required to support three different operating environments. Second, JPALS must support both the military L1 and L2 precise code P(Y) signals as well as the civilian L1 Coarse/Acquisition Code (C/A) signal. Third, JPALS may be subjected to both unintentional and intentional interference across the L1 and L2 frequencies at higher levels than those likely to be encountered by LAAS.

JPALS is comprised of two segments, the Military Ground Segment (MGS) and the MAS, which provide the accuracy, integrity, and continuity performance similar to other modern landing systems.

The MAS and MGS support JPALS Service Level 7 (SL 7) and Service Level 8 (SL 8) precision approach operations with autoland capability. An objective of growth to JPALS Service Level 9 (SL 9) is defined in the SRD [28]. JPALS Service Levels are equivalent to FAA Category I (CAT I), Category II (CAT II) and Category IIIa (CAT IIIa) precision approaches respectively.

A Space Segment provides the MGS and MAS with GPS and Satellite-Based Augmentation System (SBAS) ranging signals and orbital parameters as illustrated in Figure 1-1.

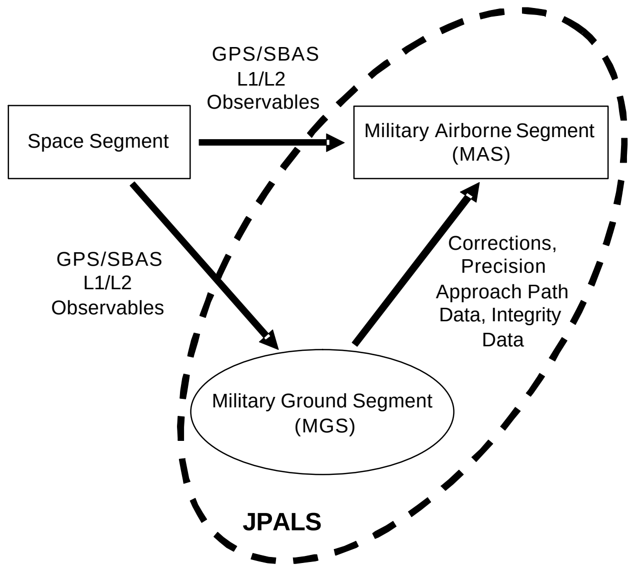


Figure 1-1 Overview of JPALS

The MGS is a safety-critical system consisting of the hardware and software to augment the GPS Standard Positioning Service (SPS) & Precise Positioning Service (PPS) to perform a precision approach and landing capability. The MGS provides differential corrections, integrity parameters, and precision approach path data that are transmitted via data broadcasts to the MAS for processing.

The MAS applies LDGPS corrections from a GBAS or MGS, to the GPS and optional SBAS ranging signals to obtain position with the required accuracy, integrity, continuity, and availability. The differentially corrected position is used, along with precision approach path data, to supply deviation signals to drive appropriate aircraft systems supporting terminal area and precision approach operations. Furthermore, using the position, velocity and time (PVT) from the airborne receiver, LDGPS could augment the availability of terminal area operations for aircraft equipped with Area Navigation (RNAV) capability.

1.2.1 Operating Environment

US forces conduct operations throughout the spectrum of threat environments. These operations may occur before, at, or beyond the forward edge of the battle area. The system must operate in an environment that includes a large number of Radio Frequency (RF) emitters (both friendly and unfriendly) and hostile electronic attack assets that operate across the electromagnetic spectrum. JPALS supports three different operating environments; Fixed Base, Tactical, and Special Mission.

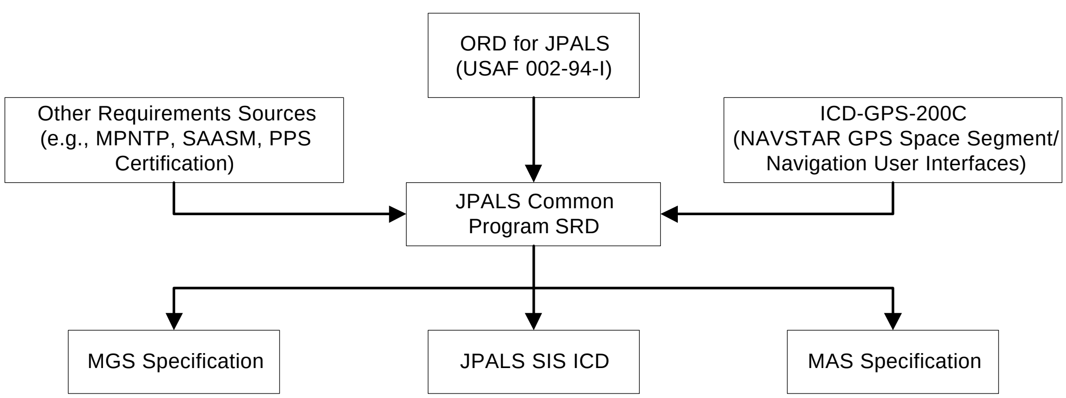
The fixed base aircraft precision approach and landing, operating environment (military and civil) is generally a prepared field with a well-established airfield infrastructure. The probability of hostile action at fixed bases can vary from low to high. Aircraft activity ranges from low to high air traffic and for a relatively long period of time. The duration of the fixed base deployment is intended to be a permanent installation. The fixed base, operating environment involves military aircraft, allied aircraft, and Civil Reserve Air Fleet (CRAF) aircraft.

The tactical aircraft precision approach and landing operating environment (military and civil) is unprepared assault strips, bare bases, or expeditionary fields with limited airfield infrastructure. There is a high potential for enemy hostile action influencing tactical operations. Sustained air traffic may not be as high as fixed bases; however, surge launch and recovery rates may exceed fixed base rates. The duration of a tactical deployment can range from several days to several months or longer. The tactical operating environment involves military aircraft and may involve allied and CRAF aircraft.

The special mission precision approach and landing operating environment may be unprepared assault strips, bare bases, expeditionary fields, and in areas with limited or no infrastructure. This operating environment may be in politically denied territory or within enemy lines, with a corresponding high potential for enemy encounter. Special mission operations may be clandestine in nature and can involve many aircraft types and numbers but for a shorter period of time in comparison to fixed base or tactical operations. Operations security usually requires communication-out operations for all aircraft.

1.2.2 JPALS Requirements Hierarchy

The MAS is part of a family of documents that establish the system, performance, and interface requirements for JPALS that have been or are being developed to completely specify JPALS characteristics. Figure 1-2 illustrates the hierarchy of the various JPALS requirements documents for Block I.



ICD	Interface Control Document	ORD	Operational Requirements Document [15]
GPS	Global Positioning System	PPS	Precise Positioning Service [16]
MAS	Military Airborne Segment	SAASM	Selective Availability and Anti-Spoofing Module
MGS	Military Ground Segment	SIS	Signal In Space
MPNTP	Master Positioning Navigation and Timing Plan		

Figure 1-2 JPALS Requirements Hierarchy for Block I

The ORD [15] contains the JPALS operational requirements, which are the primary source for the JPALS performance requirements contained in the SRD [28]. Other documents also contain requirements or capabilities that establish performance requirements that must be met by JPALS. From the SRD [28], JPALS performance requirements are then allocated to the MAS

Specification, the JPALS Signal in Space (SIS), Interface Control Document (ICD), or the MGS Specification, as applicable.

1.2.3 Evolutionary Acquisition

JPALS is being acquired and developed using an Evolutionary Acquisition strategy. JPALS capabilities are being acquired and fielded to meet user demands consistent with the necessary technology development and maturation. The initial JPALS capability or system is a JPALS tactical CAT I system followed by a fixed base CAT I system.

Subsequent JPALS capabilities are to be fielded as user needs and technology are identified and developed. A new GPS signal code (M-Code) and frequency (L5) as well as GPS III modifications are to be considered and incorporated as they become available.

1.3 Assumptions

1.4 Document Overview

This document contains the following sections:

1. Scope: Contains the project identification, system and document overviews, and a list of the terms, definitions and acronyms used in this document.

2. Applicable Documents: Provides a list of the documents referenced in this standard. References contain the document number, exact title, revision level and issue date.

3. System Requirements: Specifies the requirements for the system to which this specification applies.

4. Quality Assurance: Ensures that the requirements of sections 3 and 5 are satisfied.

5. Preparation for Delivery: Specifies the requirements for preparation and delivery, including packaging and handling of the system and its components.

Appendices: Includes a compliance matrix, vulnerability requirements, environmental testing, and issues to be resolved.

2 Reference Documents

The following documents, in the exact revision and date shown, form a part of this specification to the extent specified herein. If the document's revision or date is not indicated, the most current version of the document as of the date of this specification applies.

[1] AC 23-1309-1C, Advisory Circular, *Equipment, Systems, and Installations in Part 23 Airplanes*, 12 March 1999, Department of Transportation, Federal Aviation Administration.

[2] AC 25-1309-1A, Advisory Circular, *System Design and Analysis*, 21 June 1988, Department of Transportation, Federal Aviation Administration.

[3] AC 27-1B, Advisory Circular, *Certification of Normal Category Rotorcraft*, Change 1, 12 February 2003, Department of Transportation, Federal Aviation Administration.

[4] AC 29-2C, Advisory Circular, *Certification of Transport Category Rotorcraft*, Change 1, 12 February 2003, Department of Transportation, Federal Aviation Administration.

[5] ARINC 743A-4, ARINC Specification, *GNSS Sensor*, December 2001, Aeronautical Radio Inc., 2551 Riva Road, Annapolis, MD 21401.

[6] *Code of Federal Regulations*, Title 14, Aeronautics and Space, Chapter I, Department of Transportation, Federal Aviation Administration, subchapter C, Aircraft, Part 25, Airworthiness Standards: Transport Category Airplanes.

[7] *DoD GPS Standard Positioning Service (SPS) Performance Standard*, (no number), October 2001.

[8] CI-GRAM-500, *Performance Specification For The Global Positioning System (GPS) Receiver Application Module – Modified Standard Electronic Module-E (Mod SEM-E)*, 23 April 2003, SMC/CZU, Los Angeles AFB, CA

[9] FAA-E-2937A, Specification, *LAAS Ground Facility Specification for Category 1*, 17 April 2002, United States department of Transportation Federal Aviation Administration.

[10] ICD-GPS-200C, *NAVSTAR GPS Space Segment/Navigation User Interfaces*, IRN-200C-005R1, 14 January 2003, ARINC Research Corporation, 2250 E. Imperial Highway, Suite 450, El Segundo, CA 90245-3509.

[11] *Joint Precision Approach and Landing System (JPALS) Security Classification Guide*, TBD.

[12] *Joint Precision Approach and Landing System (JPALS) Signal-in-Space (SIS) Interface Control Document (ICD)*, 28 December 1999, DoD.

[13] MSO-C144, *Airborne Global Positioning System Antenna,* 5 July 2002, DoD, GPS Joint Program Office, User Systems Engineering, Los Angeles AFB, CA.

[14] *NAVSTAR Global Positioning System, System Protection Guide*, 13 June 1997, Headquarters Space And Missile Systems Center (AFMC), United States Air Force, Los Angeles Air Force Base (LAAFB), Los Angeles, CA 90245-4659.

[15] *Operational Requirements Document (ORD) for Joint Precision Approach and Landing System (JPALS)*, USAF-002-94-I, 8 July 2002, Air Force Flight Standards Agency.

[16] *Precise Positioning Service (PPS) Certification,* (Number TBD), (Date TBD).

[17] RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, 1 December 1992, RTCA Inc.

[18] RTCA/DO-186A, *Minimum Operational Performance Standards (MOPS) for Airborne Radio Communication Equipment Operating Within the Radio Frequency Range 117.975-137.000 MHz*, 20 October 1995, RTCA Inc.

[19] RTCA/DO-196, *Minimum Operational Performance Standards (MOPS) for Airborne VOR Receiving Equipment Operating Within the Radio Frequency Range of 108-117.95 MHz*, 17 November 1986, RTCA Inc.

[20] RTCA/DO-228, *Minimum Operational Performance Standards (MOPS) for Global Navigation Satellite System (GNSS) Airborne Antenna Equipment*, 20 October 1995, RTCA Inc.

[21] RTCA/DO-229C, *Minimum Operational Performance Standards (MOPS) for Global Positioning System/Wide Area Augmentation System Airborne Equipment*, RTCA Inc.

[22] RTCA/DO-245, *Minimum Aviation System Performance Standards (MASPS) for Local Area Augmentation System (LAAS)*, 28 September 1998, RTCA Inc.

[23] RTCA/DO-246B, *Global Navigation Satellite System (GNSS) Based Precision Approach Local Area Augmentation System Signal-in-Space - Interface Control Document,* 28 September 1998, RTCA Inc.

[24] RTCA/DO-253A, *Minimum Operational Performance Standards (MOPS) for GPS Local Area Augmentation System Airborne Equipment*, 28 November 2001, RTCA Inc.

[25] RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, 19 April 2000, RTCA Inc.

[26] SS-GPS-001A, *Selective Availability and Anti-Spoofing Module (SAASM)*, 12 March 1998.

[27] *Standard and Recommended Practices (SARPs)*, Aeronautical Telecommunications Vol. I, Radio Navigation Aids, International Civil Aviation Organization (ICAO), Annex 10, Vol. I, Amendment. 77.

[28] *System Requirements Document (SRD) for the Joint Precision Approach and Landing System (JPALS) Common Program*, April 2003, Revision 2.2, Draft V13, Electronic Systems Center, Global Air Traffic Operations/Mobility Command and Control System Program Office (ESC/GA), JPALS Integrated Product Team, Hanscom AFB, MA 01731-2103.

[29] TSO-C36e, *Airborne ILS Localizer Receiving Equipment Operating Within The Radio Frequency Range of 108-112 Megahertz (MHz)*, 25 January 1988, Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington, DC.

[30] TSO-C40c, *VOR Receiving Equipment Operating Within The Radio Frequency Range of 108-117.95 Megahertz (MHz),* 25 January 1988, Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington, DC.

[31] TSO-C161, *Ground Based Augmentation System Positioning and Navigation Equipment*, 30 May 2003, Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington, DC.

[32] TSO-C162, *Ground Based Augmentation System Very High Frequency Data Broadcast Equipment*, 30 May 2003, Department of Transportation, Federal Aviation Administration, Aircraft Certification Service, Washington, DC.

2.1 Order of Precedence

In case of a conflict between this document and the referenced documents, the order of precedence in descending order is as listed below unless otherwise noted herein:

Applicable Federal, State, or Local Laws and Regulations

JPALS ORD [15]

JPALS SRD [28]

MAS (this document)

Other referenced specifications and documents referenced in section 2.

In case of conflict between referenced documents at a lower order of precedence than this document, the more restrictive requirement applies, unless otherwise approved by the Government in the form of a change to this document or by other contractually effective means.

Lack of a requirement at a higher level of precedence or a more general requirement at a higher level of precedence is not considered a conflict. The more detailed requirement applies.

3 System Requirements

The MAS system requirements are delineated in the following subparagraphs.

3.1 System Definition and General Requirements

A block diagram of the MAS and its external and internal interfaces is shown in Figure 3-1. This diagram depicts the Global Navigation Satellite System (GNSS) SIS, a GBAS and the two system segments that make up JPALS, the MGS and the MAS.

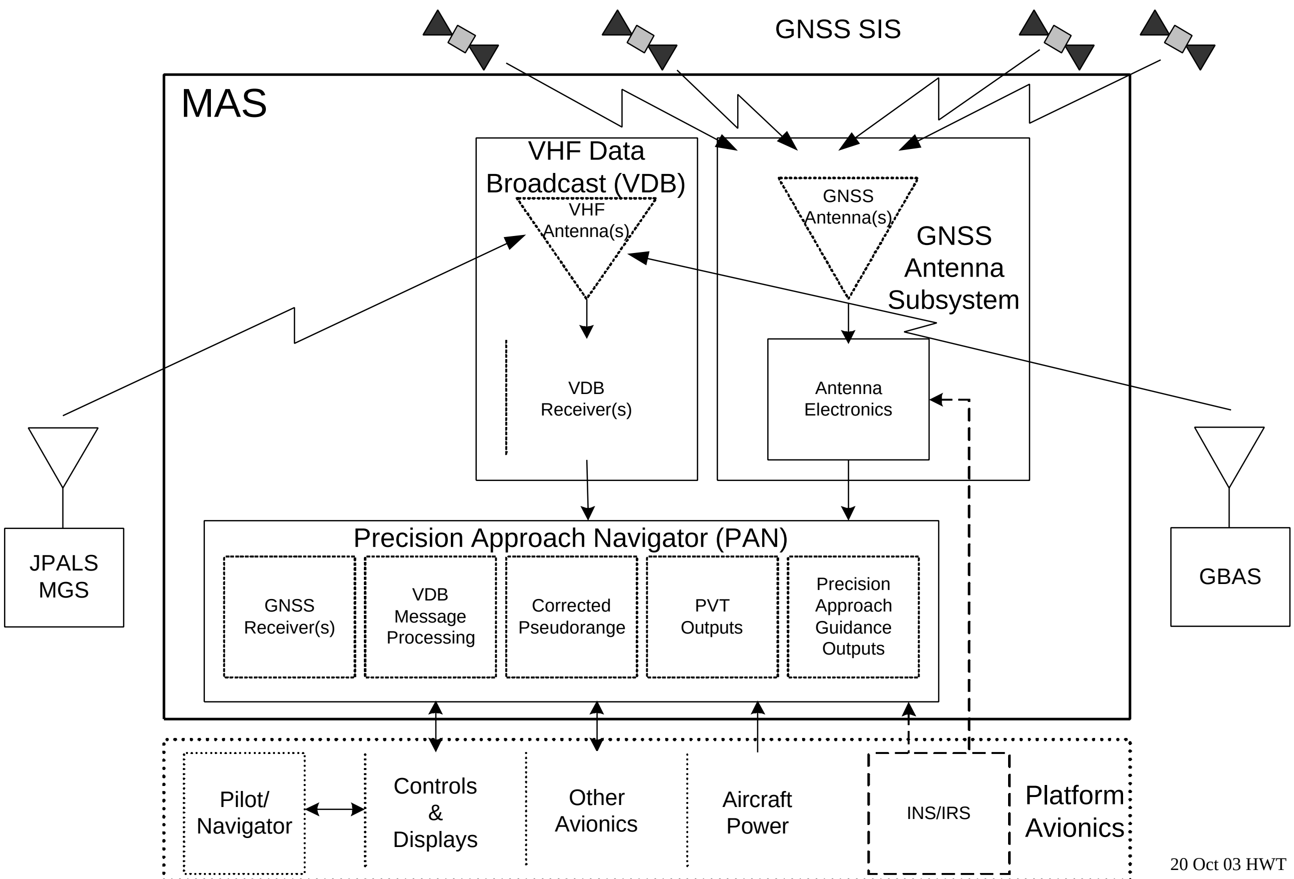


Figure 3-1 MAS Functional Block Diagram

The MGS or GBAS provide local differential pseudorange corrections, integrity parameters, and Final Approach Segment (FAS) data that are transmitted via a Very High Frequency (VHF) Data Broadcast (VDB).

The MAS receives the MGS or GBAS differential pseudorange corrections and applies them to the MAS derived GPS and optional SBAS pseudorange to obtain position with the required accuracy, integrity, continuity and availability.

The differentially corrected position is used, along with the FAS data, to supply vertical and horizontal deviation signals to drive appropriate aircraft systems supporting precision approach.

3.1.1 MAS Functions

The MAS notionally consists of the following functional elements: VDB, GNSS antenna subsystem, and Precision Approach Navigator (PAN) shown in Figure 3-1. The functions depicted are divided for figurative purposes only and are not intended to imply a specific implementation or design.

Note: *Specific MAS functional allocations will be a subject of discussion and review at Technical Interchange Meetings. Since the MAS subsystems may be designed or provided by multiple vendors, adequate specification of performance and interfaces must be accomplished to ensure interoperability.*

3.1.1.1 VDB

The VDB consists of VHF antenna(s) and VDB receiver(s). The VDB contains the hardware and software necessary to receive the differential pseudorange corrections, approach data, and other information broadcast by the MGS via VHF ground based data link. The VDB also receives broadcast by the GBAS via the ground based data link. The VDB is functionally equivalent to the VDB described in RTCA/DO-253A [24] and is compatible with ICAO SARPs [27] Annex 10 GBAS requirements.

3.1.1.2 GNSS Antenna Subsystem

The GNSS antenna Subsystem consists of GNSS antenna(s) and antenna electronics. The GNSS antenna receives the GPS and optional SBAS SIS. The GNSS antenna function may include antenna electronics for amplification, and/or to alter the GNSS antenna pattern to mitigate the effects of undesired signals.

If the antenna electronics employs beam-forming techniques it may require an attitude input. The attitude input may be provided by an Inertial Navigation Sensor (INS) or Inertial Reference System (IRS).

3.1.1.3 PAN

The PAN consists of GNSS Receiver, VDB message processing, application of pseudorange correction, computation of PVT, and output of precision approach guidance. The PAN contains the hardware and software necessary to receive and process GPS and optional SBAS ranging signals and navigation data. The PAN applies VDB differential corrections to the GPS and optional SBAS ranging signals and determines the PVT solution. The PVT solution is combined with FAS data provided by the MGS or GBAS to determine vertical and horizontal deviations. The PAN calculates protection levels associated with the aircraft position during the approach and compares them to the applicable alert limits. If the protection levels exceed the alert limits the PAN invalidates the deviation outputs.

The PAN may also receive inputs from an external INS or IRS to aid the GNSS Receiver code and carrier tracking loops or as an additional sensor input to the PAN.

3.1.2 MAS States and Modes

The MAS shall have two mutually exclusive states (see Figure 3-2) as follows:

a. On State when power is applied to the MAS equipment.
b. Off State when no power is applied to the MAS equipment.

Note: *The states and modes specified herein consider the MAS as stand alone equipment. A system integrator may need to modify the states and modes to permit operation with separate Instrument Landing System (ILS), Microwave Landing System (MLS) or Multi-Mode Receivers.*

3.1.2.1 MAS On State

While in the On State, the MAS shall provide one of the following modes of operation:

a. Operational
b. Non-Operational

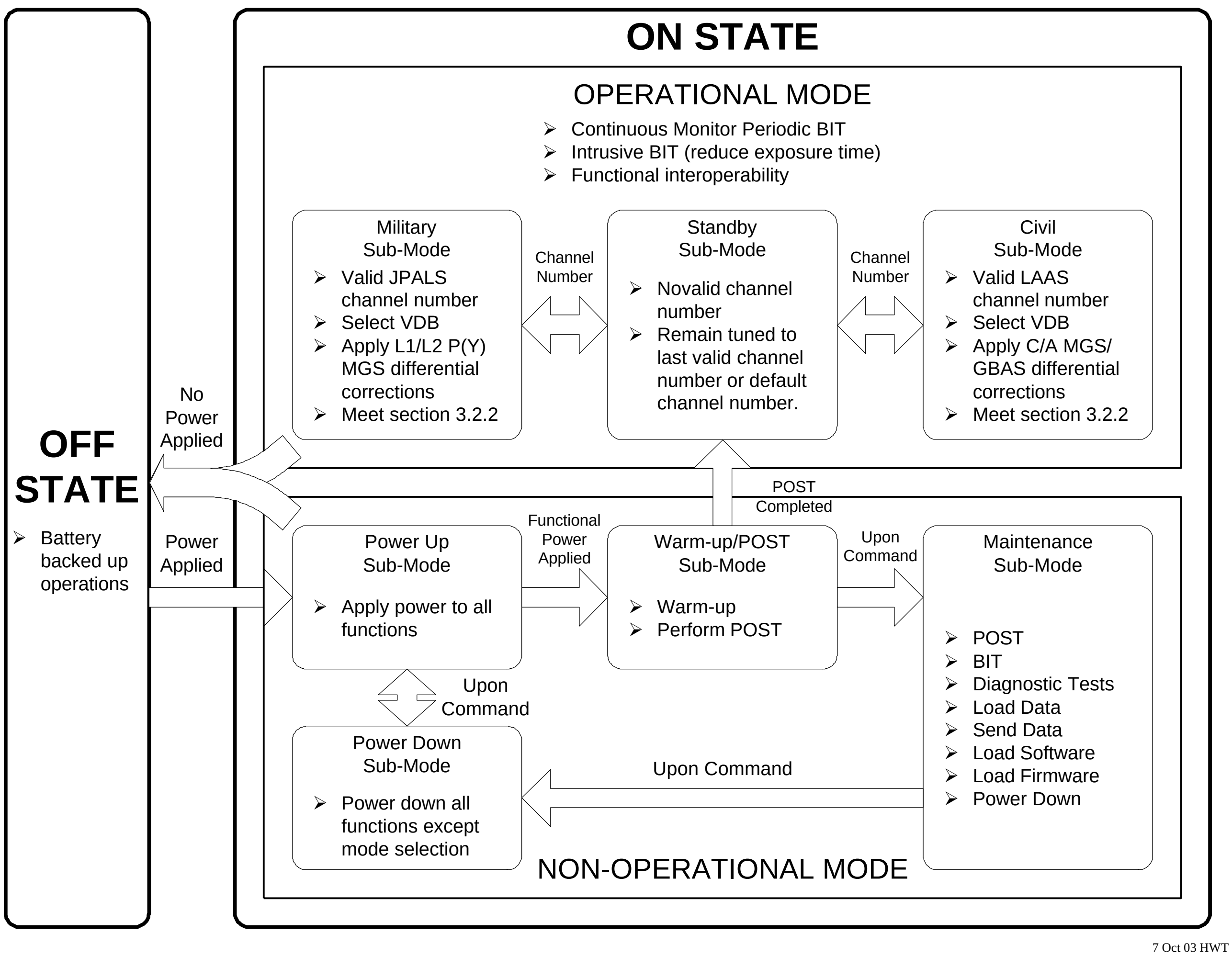


Figure 3-2 MAS States and Modes

3.1.2.1.1 Operational Mode

In the operational mode, the MAS shall provide one of the following sub-modes of operation:

a. Civil
b. Military
c. Standby

While in the operational mode, the MAS shall continuously monitor its operation by performing a periodic built-in-test (BIT) that does not inhibit performance.

While in the operational mode, the MAS may perform a BIT that may interrupt performance without impacting continued safe flight and landing, to reduce exposure time and meet integrity requirements.

3.1.2.1.1.1 Military Sub-Mode

While in the operational mode, the MAS shall enter Military Sub-Mode when a valid JPALS channel number (contained in the JPALS SIS ICD [12]) is selected by the operator.

Note: *JPALS Channel numbers may be validated by comparison to a data base, or by an algorithm that checks for valid numbers.*

The MAS shall use the channel number or equivalent means, to select the VDB.

While operating in the Military Sub-Mode, the MAS shall apply L1 or L2 P(Y) differential corrections from the MGS to the pseudorange measurements.

While operating in the Military Sub-Mode, the MAS shall meet requirements described in section 3.2.2.

3.1.2.1.1.2 Civil Sub-Mode

While in the operational mode, the MAS shall enter Civil Sub-Mode when a valid LAAS channel number (contained in the JPALS SIS ICD [12], within the range of 20001 to 39999) is selected by the operator.

Note: *LAAS channel numbers may be validated by comparison to a data base, or by an algorithm that checks for valid numbers.*

The MAS shall use the LAAS channel number or equivalent means, to select the VDB.

While operating in the Civil Sub-Mode, the MAS shall apply L1 C/A differential corrections from the MGS or GBAS to L1 C/A pseudorange measurements

While operating in the Civil Sub-Mode, the MAS shall meet the additional requirements described in section 3.2.2.

3.1.2.1.1.3 Standby Sub-Mode

While in the operational mode, the MAS shall enter Standby Sub-Mode if a valid JPALS or LAAS channel number is not selected or has not been selected by the operator.

While in the Standby Sub-Mode, the MAS shall remain tuned to the last valid JPALS or LAAS channel number selected or default (BIT channel number) if a valid channel has never been selected.

3.1.2.1.2 Non-Operational mode

In the non-operational mode the MAS shall select one of the following sub-modes:

a. Power-Up
b. Warm-Up/Power On Self Test (POST)
c. Maintenance
d. Power-Down

3.1.2.1.2.1 Power-Up Sub-Mode

The MAS shall transition to the Power-Up Sub-Mode when power is applied.

The MAS shall transition to the Power-Up Sub-Mode from the Power-Down Sub-Mode when commanded.

In the Power-Up Sub-Mode the MAS shall apply power to all functions.

3.1.2.1.2.2 Warm-Up/POST Sub-Mode

When power is applied to all functions the MAS shall transition from the Power-Up Sub-Mode and initiate the Warm-Up/POST Sub-Mode.

POST shall be performed as the unit warms up. Tests that require warm up are delayed until the warm up period has expired.

After the Warm-Up/POST Sub-Mode has completed the MAS shall transition to the operational mode, unless it receives a command to enter Maintenance Sub-Mode.

3.1.2.1.2.2.1 Warm-Up Time

The MAS shall meet all performance requirements within 2 minutes of the application of power and selection of a mode other than Off.

3.1.2.1.2.3 Maintenance Sub-Mode

While in the non-operational mode and when Maintenance Sub-Mode is commanded the MAS shall perform the following maintenance tasks when selected:

a. POST.
b. BIT.

c. Diagnostic tests.
d. Load data from an external source.
e. Send data to an external destination.
f. Load operational or maintenance software or firmware.
g. Go to Power-Down Sub-Mode.
h. Exit Maintenance Sub-Mode.

The MAS shall transition to Operational mode from Maintenance Sub-Mode when POST is successfully completed and Maintenance Sub-Mode is exited.

3.1.2.1.2.4 Power-Down Sub-Mode

The MAS shall transition to the Power-Down Sub-Mode when commanded.

In the Power-Down Sub-Mode the MAS shall power down all functions except those required to detect the selection of other modes with external power applied.

3.1.2.2 MAS Off State

While in the Off State, the MAS shall only permit its battery backed up operations until external power is applied.

3.1.3 MAS Interface Definition

3.1.3.1 MAS External Interface Definition

The MAS external interfaces (see Table 3-1) are comprised of MGS or GBAS ground station radiated signals, GPS or optional SBAS satellite radiated signals and aircraft platform connections.

Table 3-1 MAS External Interface Definition

External Interface	***ICD Title***	***Data Transferred***
GBAS VDB	LGF Specification [9]	LDGPS Differential Corrections, Ground Station data, FAS
JPALS MGS VDB	JPALS Signal In Space ICD [12]	LDGPS Differential Corrections, Ground Station data, FAS
JPALS MGS	JPALS Signal In Space ICD [12]	LDGPS Differential Corrections, Ground Station data, FAS
GNSS SIS (Space Segment)	ICD-GPS-200C [10], NAVSTAR GPS Space Segment Navigation User Interfaces	GPS Ranging Signals and Navigation Data
GNSS SIS (SBAS)	RTCA/DO-229C [21], MOPS for GPS WAAS Airborne Equipment	SBAS Ranging Signals and Navigation Data
Aircraft platform	Avionics ICD (TBD)	Lateral and Vertical Deviations, PVT (optional), Integrity Status, Control and Maintenance data.

3.1.3.2 MAS Internal Interface Definition

The MAS internal interfaces shall use open architecture designs.

3.1.3.2.1 GNSS Receiver Interface

The GPS host application equipment (HAE) interface shall support a full digital interface with a beamforming antenna electronics unit, where each individual satellite signal is transmitted over the digital interface.

The HAE interface shall support closed loop beamforming.

3.2 Requirements and Characteristics

The following subsections describe the requirements for MAS system performance and its physical characteristics.

3.2.1 Functional Requirements

This section defines the high-level functional requirements for the MAS.

3.2.1.1 Approach and Landing Guidance

The MAS shall compute a precision approach and landing navigation solution based on differential corrections received from the MGS or GBAS, GPS measurements and GPS navigation message data.

The MAS shall monitor the integrity of its navigation solution using integrity data from the MGS or GBAS and MAS GPS measurement data.

The MAS shall only use and apply MGS corrections that match in code (C/A or P(Y)) and frequency (L1 or L2) the satellites tracked by the MAS.

The MAS shall only use and apply GBAS corrections that match the satellites tracked by the MAS.

The MAS shall accept the input of data and provide output data to support a means for the flight crew to select and verify the desired approach is activated.

The MAS shall provide guidance only when the FAS and differential corrections are from the same MGS or GBAS.

The MAS shall provide guidance data to the aircraft that the aircraft can use to align laterally and vertically with the computed path.

The MAS shall provide the distance to the landing threshold point (LTP)/fictitious threshold point (FTP) while the aircraft is on a FAS.

The MAS shall provide an indication to the aircraft if a loss of integrity is detected.

The MAS shall (optionally) provide guidance data to the aircraft that the aircraft uses to align laterally and vertically along a missed approach path to the designated missed approach waypoint.

The MAS shall (optionally) provide range to the missed approach waypoint while performing a missed approach operation.

3.2.1.2 Interoperability

The MAS shall provide the functions specified herein when landing at airfields equipped with GBAS, as specified in ICAO SARPS [27] Annex 10.

3.2.2 Performance Requirements

This section defines the performance characteristics of the MAS.

3.2.2.1 General MAS Requirements

The MAS shall output precision approach guidance under the conditions and in accordance with the requirements specified within this document.

3.2.2.1.1 Airworthiness

The design and manufacture of the MAS functions shall support installation so as not to impair the airworthiness of the aircraft.

3.2.2.1.2 Intended Function

The MAS shall perform its intended function, as defined by this document and the manufacturer.

3.2.2.1.3 Design Assurance

MAS hardware and software shall be designed and developed such that the probability of providing misleading information and the probability of loss of function, meet the aircraft integrity and continuity requirements, respectively.

Note 1: *This requirement must be met when the equipment is in its installed configuration for the most stringent operation supported. To demonstrate compliance, it will be necessary to conduct a safety assessment to evaluate the system's implementation against known failure conditions. For Civil certification the MAS functions safety assessment should be based upon the criteria of AC 23.1309-1() [1] for CFR [6], Part 23 aircraft, and AC 25.1309-1() [2] . for CFR [6], Part 25 aircraft, AC 27-1() [3] for normal category rotorcraft, and AC 29-2() [4] for transport category rotorcraft.*

Note 2: *Failure conditions of MAS functions that cause out-of-tolerance error conditions during a SL 7 approach, without identifying the data as invalid, can be classified as hazardous/severe-major.*

3.2.2.2 VDB Receiver Subsystem

This section contains requirements for the VDB data link receiver subsystem. Figure 3-3 is a representative functional block diagram for the VDB receiver. This figure is shown for illustrative purposes only and is not intended to imply a specific implementation or design.

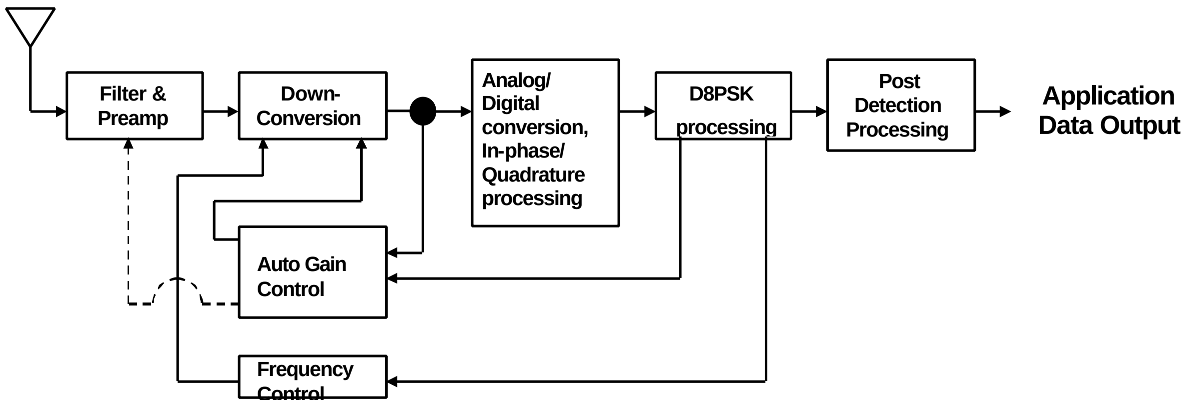


Figure 3-3 VDB Receiver Functional Block Diagram

3.2.2.2.1 General Requirements

The requirements specified in section 3.2.2.2 shall be verified with standard test signals and power levels as specified in RTCA/DO-253A [24] section 2.5.2.1.1.

Note 1: *Power levels specified for the VDB are measured as the average power over the period of the unique word in the training-sequence portion of the message.*

Note 2: *The requirements of section 3.2.2.1.3 have been developed to operate in the Precision Approach coverage volume. This does not preclude the use of the LAAS signal-in-space outside the Precision Approach coverage volume.*

Note 3: *Determination of the Message Failure Rate (MFR) requires additional test equipment to verify the Cyclic Redundancy Check (CRC), as the CRC is not verified by the VDB receiver function. Instead, it is verified by the PAN function to reduce the hazard classification of the VDB receiver.*

3.2.2.2.2 Tuning

3.2.2.2.2.1 Frequency Range

The VDB receiver subsystem shall be capable of tuning frequencies in the range of 108.000 to 117.975 MHz in increments of 25 kHz.

Note: *In accordance with ICAO SARPs [27] Annex 10, operational frequency assignments will be assigned on 25 kHz centers in the range from 108.025 MHz to 117.950 MHz inclusive.*

3.2.2.2.2.2 Frequency Selection

The VDB receiver subsystem shall accept input of either a VDB frequency or a channel number.

The channel number (*N*) shall be converted to a VDB frequency (*F*) using the equation given in section 3.2.2.3.4.

Selection of a channel number shall only result in the VDB receiver subsystem tuning to frequencies within the range 108.000 to 117.975 MHz.

3.2.2.2.2.3 Response Time

The VDB receiver subsystem shall output messages from the new ground station within 3 seconds after it receives the command to select (3.2.2.2.2.2) a new ground station frequency.

Note: *Assuming the new ground station is available and is within the dynamic range of the receiver.*

3.2.2.2.3 Data Latency

The VDB receiver subsystem shall output all bits of a desired ground station message within 125 milliseconds of the arrival of the last bit of that message at the VDB antenna.

Note: *The data latency only applies after the VDB is providing messages as specified in section 3.2.2.2.2.3.*

3.2.2.2.4 Data Format Decoding

The VDB receiver subsystem shall properly demodulate and decode the VHF data broadcast signal specified in DO-246B [23]and the JPALS SIS ICD [12].

3.2.2.2.5 Message Failure Rate

The VDB receiver subsystem shall achieve a message failure rate (MFR) less than or equal to one failed message per 1000 full-length (222 bytes) application data messages, while operating over an input signal (S) power range between S_{min} = –87 dBm and S_{max} = –1 dBm, provided that the variation in the average received signal power between successive bursts in a given time slot does not exceed ΔS_{max} = 40 dB.

Note 1: *The VDB field strength has been specified to achieve a minimum signal power at the receiver of S_{min}, as shown in the VDB Link Budget given in RTCA DO-245 [22].*

Note 2: *Successive bursts are defined as consecutive, scheduled bursts from a ground transmitter. The ground system transmitter broadcasts a burst in at least every fifth consecutive frame for each assigned time slot being used.*

Note 3: *This requirement includes the condition of the received power in consecutive slots in a given frame varying from S_{min} to S_{max}.*

While operating over an input power range between S_{min} and S_{max}, if the average received signal power variation between successive frames in a given time slot exceeds ΔS_{max}, the MFR shall not exceed 60%.

3.2.2.2.6 VDB Signal Tracking Requirements

Note: *The VDB field strength has been specified to achieve a minimum signal power at the receiver of –87 dBm.*

3.2.2.2.6.1 Carrier Frequency Capture Range

The VDB receiver subsystem shall acquire and maintain lock on signals with a frequency offset of up to ±418 Hz from the nominal assigned frequency.

Note: *The frequency stability of the ground subsystem (±236 Hz at 117.975 MHz), and the worst-case Doppler shift due to the motion of the aircraft (±182 Hz at 900 knots), are reflected in the above requirement. The dynamic range of the automatic frequency control (AFC) should also consider the frequency-stability error budget of the airborne VDB receiver subsystem itself.*

3.2.2.2.6.2 Carrier Frequency Slew Rate

The VDB receiver subsystem shall acquire and maintain lock on signals when the received carrier frequency is varied within the range specified in section 3.2.2.2.6.1 at a rate of 15 Hz per second.

Note: *This assumes ±0.1 ppm/second frequency drift for the VDB transmitter and ±0.03 ppm/second frequency drift due to Doppler changes when the aircraft is subjected to 1g acceleration at 117.975 MHz.*

3.2.2.2.6.3 Symbol Rate Tolerance

The VDB receiver subsystem shall acquire and maintain lock on signals for received symbol rates between 10499.45 and 10500.55 symbols per second.

Note: *This includes ±50 ppm for the transmitter symbol rate tolerance and ±1.5 ppm for aircraft Doppler at 900 knots. This totals ±51.5 ppm.*

3.2.2.2.7 Co-Channel Rejection

3.2.2.2.7.1 VDB as the Undesired Signal

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of an undesired co-channel VDB signal that is either:

a. assigned to the same time slot(s) and whose power level is 26 dB below the desired VDB power level; or
b. assigned a different time slot(s) and whose power is up to +15 dBm at the receiver input.

3.2.2.2.7.2 VOR as the Undesired Signal

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of an undesired co-channel VHF Omni-directional Range (VOR) signal whose power level is 26 dB below the desired VDB power level.

3.2.2.2.7.3 ILS Localizer as the Undesired Signal

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of an undesired co-channel ILS localizer signal whose power level is 26 dB below the desired VDB power level.

3.2.2.2.8 Adjacent Channel Rejection

3.2.2.2.8.1 1st Adjacent 25 kHz Channels (±25 kHz)

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of simultaneously transmitted undesired signals offset by 25 kHz on either side of the desired channel whose power levels are:

a. 18 dB above the desired VDB power level when the undesired signal is another VDB signal assigned to the same time slot(s): or
b. Equal to the desired VDB power level when the undesired signal is a VOR: or
c. Equal to the desired VDB power level when the undesired signal is an ILS localizer.

3.2.2.2.8.2 2nd Adjacent 25 kHz Channels (±50 kHz)

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of a transmitted undesired signal offset by 50 kHz on either side of the desired channel whose power level is either:

a. 43 dB above the desired VDB power level when the undesired signal is another VDB source assigned to the same time slot(s); or.
b. 34 dB above the desired VDB power level when the undesired signal is a VOR; or
c. 34 dB above the desired VDB power level when the undesired signal is an ILS localizer.

3.2.2.2.8.3 3rd Adjacent 25 kHz Channels (±75 kHz) and Beyond

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of a transmitted undesired signal offset by 75 kHz or more on either side of the desired channel whose power level is either:

a. 46 dB above the desired VDB power level when the undesired signal is another VDB source assigned to the same time slot(s); or
b. 46 dB above the desired VDB power level when the undesired signal is a VOR; or
c. 46 dB above the desired VDB power level when the undesired signal is an ILS localizer.

Note: *With no on-channel VDB signal present, the VDB receiver subsystem should not output data from an undesired VDB signal on any other assignable channel.*

3.2.2.2.9 Out-of-Band Rejection

3.2.2.2.9.1 VDB Interference Immunity

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of one or more signals having the frequency and total interference levels shown in Table 3-2.

Table 3-2 Frequency and Power of Undesired Signals

Frequency	***Maximum Level of Undesired Signals at the Receiver Input (dBm)***
50 kHz up to 88 MHz	-13
88 MHz to 107.900 MHz	VHF FM Broadcast (see section 3.2.2.2.9.2.)
108.000 MHz to 117.975 MHz	Excluded
118.000 MHz	-44
118.025 MHz	-41
118.050 MHz up to 1660.5 MHz	-13

Note: *The relationship is linear between adjacent points designated by the above frequencies.*

3.2.2.2.9.2 FM Immunity

3.2.2.2.9.2.1 Desensitization

The VDB receiver subsystem shall meet the requirements specified in section 3.2.2.2.5 in the presence of VHF FM broadcast signals with signal levels shown in Table 3-3 and Table 3-4.

Table 3-3 Desensitization Frequency and Power Requirements That Apply for VDB Frequencies 108.000 to 111.975 MHz

Frequency	***Maximum Level of Undesired Signals at the Receiver Input (dBm)***
88 MHz ≤ f ≤ 102 MHz	+15
106 MHz	+10
107 MHz	+5
107.9 MHz	-10

Note 1: *The relationship is linear between adjacent points designated by the above frequencies.*

Note 2: *This desensitization requirement does not apply to channels 108.000, 108.025 and 108.050 MHz for FM carriers above 107.7 MHz.*

Table 3-4 Desensitization Frequency and Power Requirements That Apply for VDB Frequencies 112.000 to 117.950 MHz

Frequency	*Maximum Level of Undesired Signals at the Receiver Input (dBm)*
88 MHz ≤ f ≤ 104 MHz	+15
106 MHz	+10
107 MHz	+5
107.9 MHz	0

Note 3: *The relationship is linear between adjacent points designated by the above frequencies.*

3.2.2.2.9.2.2 Intermodulation Rejection

The VDB receiver subsystem shall meet the requirements of section 3.2.2.2.5 in the presence of interference from third order intermodulation products from two VHF frequency modulated (FM) broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 72 \le 0 \qquad \textbf{Equation 3-1}$$

for VHF FM sound broadcasting signals in the range 107.7 – 108 MHz and

$$2N_1 + N_2 + 3\left(24 - 20\log\frac{\Delta f}{0.4}\right) \le 0 \qquad \textbf{Equation 3-2}$$

for VHF FM sound broadcasting signals below 107.7 MHz, where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDB frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VDB receiver input.

Neither level shall exceed the desensitization criteria set forth in section 3.2.2.2.9.2.

$$\Delta f = 108.1 - f_1 \qquad \text{Equation 3-3}$$

Where:

f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

The equal-level, two-signal inter-modulation requirement is depicted in Figure 3-4.

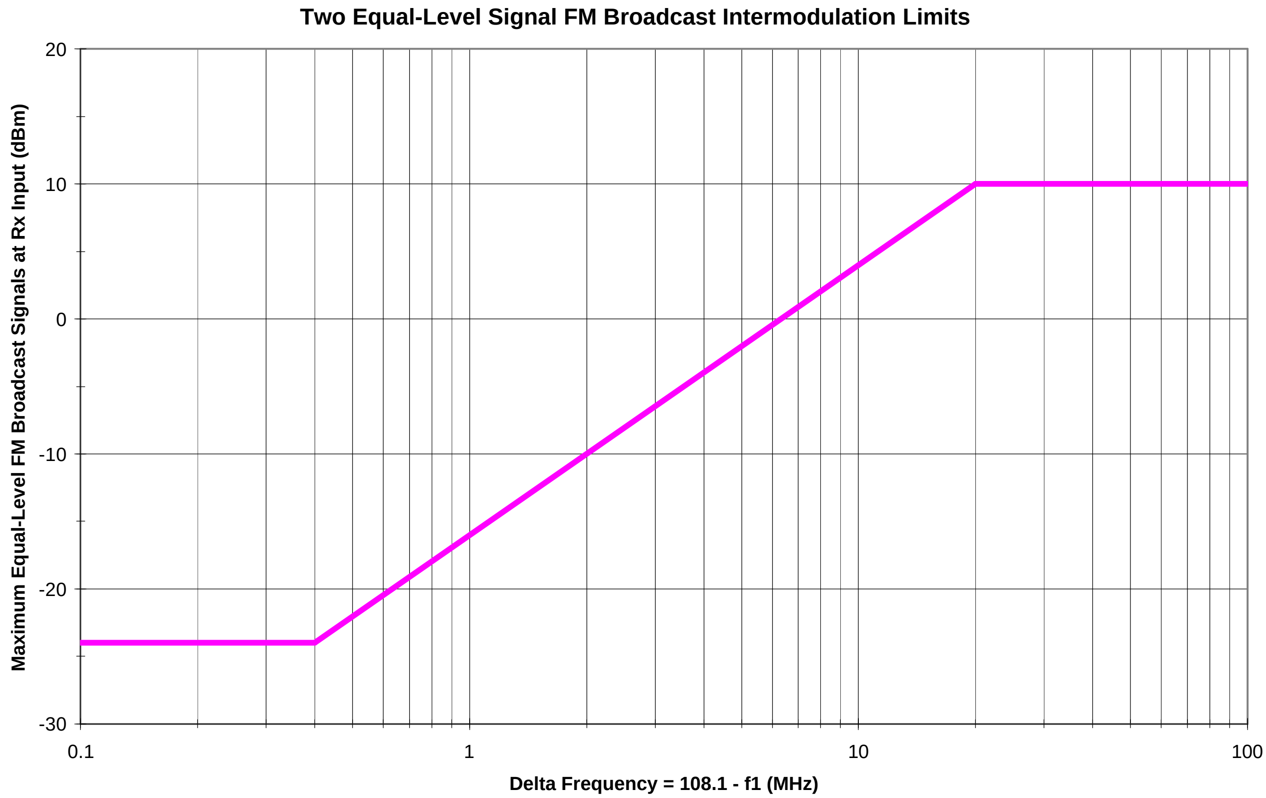


Figure 3-4 Maximum Tolerable Equal-Level FM Broadcast Signals

3.2.2.2.9.3 Burn Out Protection

The VDB receiver subsystem shall survive the application of a +20 dBm signal at the receiver input without damage throughout the frequency range of 50 kHz to 1660.5 MHz.

3.2.2.2.10 Receiver-to-Antenna Interface

3.2.2.2.10.1 Receiver Voltage Standing Wave Ratio (VSWR)

The VSWR at the receiver input terminal shall not exceed 4:1 on any selectable channel.

3.2.2.2.10.2 Antenna Characteristics

The requirements in this section apply to VDB antennas included as part of the VDB equipment. The VDB antenna requirements for horizontally polarized antennas are contained in section 3.2.2.2.10.2.1 and the requirements for vertically polarized antennas are contained in section 3.2.2.2.10.2.2.

Note 1: *The following requirements are not intended to preclude the use of existing antennas previously approved under other RTCA MOPS requirements (and associated TSO certifications) or prior regulatory approvals. This includes, but is not limited to, antennas approved under TSO-C36e [29], Airborne ILS Localizer Receiving Equipment or TSO-C40c [30], VOR Receiving Equipment.*

Note 2: *Refer to RTCA/DO-253A [24] section 3.12 for rejection of out-of-and- signals by the installed VDB antenna.*

3.2.2.2.10.2.1 Horizontally Polarized Antenna Characteristics

Note: *The antenna requirements in this section are consistent with those requirements in RTCA/DO-196 [19].*

3.2.2.2.10.2.1.1 Horizontal Antenna Gain

Over the frequency range 108.000 to 117.975 MHz, the reception of the horizontally polarized component of radiated signals in the horizontal plane from the forward and rearward directions shall not be down more than 10 dB when compared to the maximum output response of a standard horizontal dipole antenna which is resonant at 113.000 MHz and mounted 25.4 cm (10 inches) above the ground plane.

At any frequency within 108.000 to 117.975 MHz, the difference between the maximum and the minimum reception of the horizontally polarized component of radiated signals from any direction in the horizontal plane shall not exceed 20 dB.

3.2.2.2.10.2.1.2 Horizontal Antenna VSWR

When the antenna to be used with the receiver is designed for use with a transmission line, over the frequency range of 108.000 to 117.975 MHz, the VSWR produced on the antenna transmission line by the antenna shall not exceed 6:1.

3.2.2.2.10.2.2 Vertically Polarized Antenna Characteristics

Note 1: *The antenna requirements in this section are consistent with those requirements in RTCA/DO-186A [18].*

Note 2: *VHF air-ground communication systems operate with vertically polarized antennas. VDB installations also utilizing vertically polarized antennas will not be able to realize the approximately 15 dB of cross-polarization rejection afforded VDB installations utilizing horizontally polarized antennas. This will necessitate additional isolation from other sources, which may not be achievable on certain aircraft.*

3.2.2.2.10.2.2.1 Vertical Antenna Gain

Over the frequency range of 108.000 to 117.975 MHz, when the antenna is mounted on a 4’ x 4’ (or larger) ground plane, the reception of the vertically polarized component of a radiated signal in the horizontal azimuth plane shall not be down more than 6 dB when compared to a standard vertically polarized monopole antenna.

At any frequency within 108.000 to 117.975 MHz, when the antenna is mounted on a 4’ x 4’ (or larger) ground plane, the difference between the maximum and the minimum reception of the vertically polarized component of radiated signals from any directions in the horizontal azimuth plane shall not exceed 6 dB.

3.2.2.2.10.2.2.2 Vertical Antenna VSWR

Over the frequency range of 108.000 to 117.975 MHz, when the antenna is mounted on a 4' x 4' (or larger) ground plane, the VSWR produced on the antenna transmission line by the antenna shall not exceed 3:1.

3.2.2.3 Precision Approach Navigator Subsystem

The JPALS MAS PAN is functionally equivalent to the LAAS PAN.

3.2.2.3.1 General

The PAN equipment receives the ground station messages that include differential corrections. The differential corrections are added to the ranging measurements and used to compute a highly accurate navigation solution with high integrity. The PAN equipment also receives approach data from the ground station messages and makes a selection based on the pilot's input. From this information, the PAN equipment computes guidance for the approach that has been selected.

3.2.2.3.2 Interference and Dynamics Environment

Unless otherwise stated, the requirements for Civil Sub-Mode given in section 3.1.2.1.1.2 of this document shall be met under the interference environment defined in JPALS SRD [28] Appendix D (classified version) and within the envelope of instantaneous antenna(s) dynamics defined by CI-GRAM-500 [8] table 3.3-1.

Unless otherwise stated, the requirements for Military Sub-Mode given in section 3.1.2.1.1.1 of this document shall be met under the interference environment defined in JPALS SRD [28] Appendix D (classified version) and within the envelope of instantaneous antenna(s) dynamics defined by CI-GRAM-500 [8] table 3.3-1.

3.2.2.3.3 Approach and Reference Station Selection

The PAN shall accept input of the 5-digit channel number (20000-39999) or accept input of a Reference Path Data Selector (RPDS).

Note 1: *The control head may also allow selection of channels or frequencies to support ILS, MLS and SBAS.*

3.2.2.3.4 Frequency Mapping

If the PAN converts the channel number (*N*) to a RPDS, it shall be determined as follows:

$$RPDS = (N - 2000) \cdot div \cdot 411 \qquad \textbf{Equation 3-4}$$

Where:

x div y = k, the integer part of the quotient x/y

If the PAN converts the channel number (*N*) to a VDB frequency (*F*), it shall determine the frequency as follows:

$$F(MHz) = 108.00 + ((N - 2000) \cdot \mathrm{mod} \cdot 411) * 0.025 \qquad \textbf{Equation 3-5}$$

Where:

$$x \cdot \mathrm{mod} \cdot y = x - (x \cdot div \cdot y) * y$$

Note 1: *The value of 411 was selected to ensure that channel numbers for approaches served by the same ground system have at least two unique digits, to reduce the likelihood of inadvertent selection of the wrong approach. N is in the range 20000 to 39999. Values of N where ((N-20000) mod 411) > 399 are unusable because they map to frequencies above 117.975 MHz.*

Note 2: *Some values of N map to the frequencies 108.000 and 117.975 MHz, which are not included in the ICAO SARPs [27] Annex 10 assignable frequency range.*

3.2.2.3.5 *GNSS Receiver Function*

3.2.2.3.5.1 Ranging Sources

PAN equipment shall automatically select ranging sources for use in the navigational computation.

The PAN shall be capable of using GPS satellites.

Note: *The use of SBAS satellites is optional.*

3.2.2.3.5.2 Sensitivity and Dynamic Range

The PAN equipment (GNSS Receiver) shall be capable of tracking GPS satellites within the signal power range at the GNSS Antenna and in the presence of background thermal noise density as specified in Table 3-5.

The PAN shall be capable of tracking SBAS satellites within the signal power range at the GNSS Antenna and in the presence of background thermal noise density as specified in Table 3-5, if optional SBAS ranging sources are used.

Table 3-5 Sensitivity and Dynamic Range at the GNSS Antenna

GPS Signal	Minimum Power	Maximum Power	Background Thermal Noise Density
L1 C/A	-128.5 dBm	-114 dBm	-176.6 dBm/Hz
L1 P(Y)	-133 dBm	-114 dBm	-176.6 dBm/Hz
L2 P(Y)	-136 dBm	-114 dBm	-176.6 dBm/Hz
SBAS	-137 dBm	-114 dBm	-176.6 dBm/Hz

Note 1: *Figure 3-5 is an example of integrating a GNSS Receiver (ARINC 743A-4 [5]) with the antenna L1 C/A signal power shown in Table 3-5.*

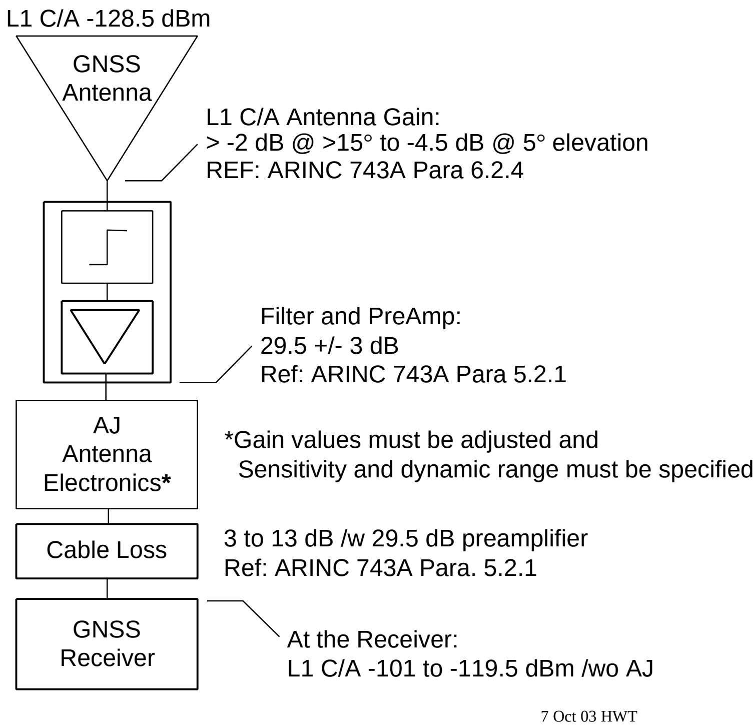


Figure 3-5 L1 C/A Sensitivity and Dynamic Range

Note 2: *Installations of equipment interoperable with an RTCA/DO-228 [20] antenna without preamplifier require less than 1.5 dB of loss between the antenna and the receiver, including loss due to coupling. This equipment should indicate in the installation instructions that this equipment is intended for installation with an RTCA/DO-228 [20] antenna without a preamplifier.*

Note 3: *Installations of equipment that are not interoperable with the standard antenna require that the manufacturer specify the minimum and maximum tolerable loss for installation. These limitations should be included in the installation instructions for this equipment. In addition, if the antenna component of the non-standard setup does not comply with the specification for the standard antenna, then the sensitivity and dynamic range must be modified based upon the antenna gain.*

Note 4: *If the antenna is also non-standard, or if a lower mask angle (< 5 degrees) is to be used, then the gain values must be adjusted, and the sensitivity and dynamic range specified.*

Note 5: *RTCA DO-253A [24] requires the PAN equipment to withstand, without damage, an in-band C/A L1 Continuous Wave (CW) signal of +20 dBm input to the preamplifier (at the receiver port or antenna port, as applicable).*

Note 6: *Figure 3-6 and Figure 3-7 are examples of integrating a CI-GRAM-500 with antenna L1 P(Y) and L2 signal powers respectively, shown in Table 3-5.*

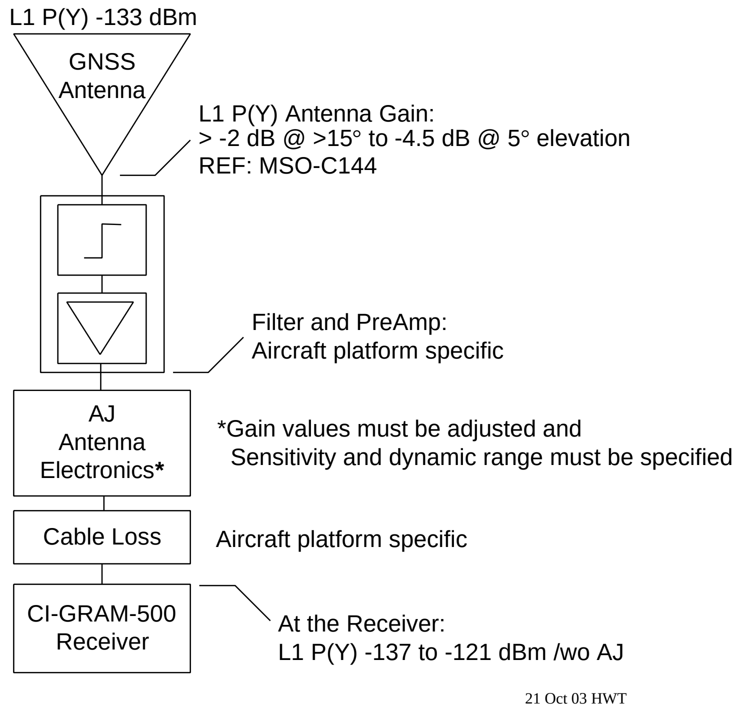


Figure 3-6 L1 P(Y) Sensitivity and Dynamic Range

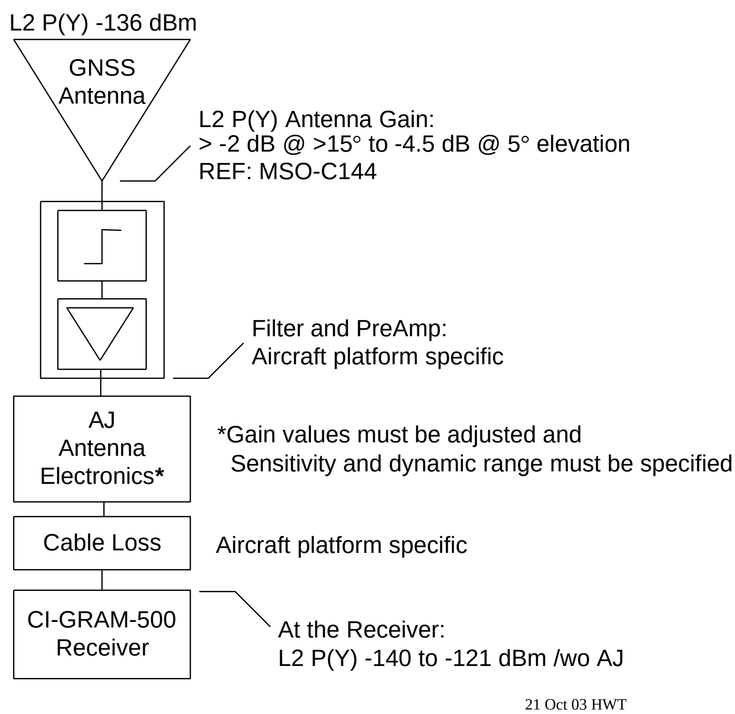


Figure 3-7 L2 P(Y) Sensitivity and Dynamic Range

3.2.2.3.5.3 GPS Signal Processing

PAN equipment shall process the GPS signals and necessary data described in the *ICD-GPS-200C* [10]. The GPS ionospheric corrections shall not be applied. A tropospheric correction as defined in the GPS SPS [7] shall not be applied.

The PAN equipment shall continue to collect and decode ephemeris and clock parameters for all ranging sources being used in the navigation solution.

If the PAN is tracking both C/A and P(Y) codes for the same ranging source, then the ephemeris and clock parameters shall be decoded by use of the P(Y) code.

The PAN shall retain multiple sets of GPS ephemeris and clock parameters to ensure that differential corrections can continue to be applied following an issue of data (IOD) change in the ground station Type 1 message (section 3.2.2.3.7.1.3).

The PAN equipment shall apply the satellite clock correction (including relativistic corrections) derived from the clock parameters in sub frame 1 of the GPS navigation message (refer to the ICD-GPS-200C [10]) after smoothing the pseudorange measurement (section 3.2.2.3.5.5).

Note: *Equipment should be able to track satellites under conditions of ionospheric scintillation that could occur during solar maximum at auroral and equatorial latitudes. There is insufficient information to characterize scintillation and define appropriate requirements and tests for inclusion in this document. However, equipment should be able to track satellites through phase jitter and amplitude fading that can result from scintillation. New requirements may be defined when ionospheric effects can be adequately characterized.*

The GNSS Receiver shall comply with SS-GPS-001A [26] (Black Key).

The GNSS Receiver shall possess Direct Y-code acquisition capability.

The GNSS Receiver shall simultaneously process up to twelve (12) independent C/A or P(Y) satellites.

The GNSS Receiver measurement outputs shall conform to the following:

a. The output observables shall not have selective availability (SA) removed.

b. No atmospheric corrections shall be applied to pseudorange measurements.

c. The satellite clock correction and relativistic correction of ICD-GPS-200C [10] paragraph 20.3.3.3.3.1 shall be applied to pseudorange measurements.

d. The group delay correction of ICD-GPS-200C [10] paragraph 20.3.3.3.3.2 shall be applied to SPS mode pseudorange measurements.

e. The ionospheric correction of ICD-GPS-200C [10] paragraph 20.3.3.3.3.3 shall not be applied to any pseudorange measurements.

f. Earth rotation effects during signal transmission shall not be applied to any pseudorange measurements.

The GNSS Receiver shall measure each set of pseudoranges (to all satellites being tracked) simultaneously, and time tag them with one time stamp indicating the time of measurement.

The GNSS Receiver shall measure each set of carrier phases (to all satellites being tracked) simultaneously and time tag them with one time stamp indicating the time of measurement.

The GNSS Receiver shall simultaneously take the first pseudorange and first carrier phase measurement of each 1-second GPS epoch, and synchronize them to the top of epoch within 2 μ seconds.

Each GNSS Receiver measurement shall be statistically independent, and not extrapolated from previous measurements.

The GNSS Receiver shall form a carrier-to-noise power ratio (C/No) measurement post correlation.

The GNSS Receiver C/No measurement shall remain accurate under the presence of jamming (TBD).

The GNSS Receiver pseudorange output rate shall be no less than 2Hz, 10Hz desired.

The GNSS Receiver carrier phase output rate shall be no less than 10Hz.

The GNSS Receiver output resolution of the pseudorange measurement shall be < 1.0 cm.

The GNSS Receiver output resolution of the carrier phase measurements shall be <1.0 mm.

The GNSS Receiver output data time tags shall be accurate to within 100 nanoseconds.

Inertial input data, if used to aid the carrier loops, must be consistent with the GNSS Receiver carrier phase bias and noise accuracy requirements.

3.2.2.3.5.3.1 Civil Mode GPS Tracking Constraints

For early-minus-late (E-L) delay lock loop (DLL) discriminator tracking of GPS satellites, the pre-correlation bandwidth of the installation, the correlator spacing, and the differential group delay shall be within the ranges as defined in Table 3-6.

Table 3-6 GPS Tracking Constraints for E-L DLL Discriminators

Region in Figure 3-8	***3 dB Pre-correlation bandwidth, BW***	***Average Correlator Spacing (C/A chips)***	***Instantaneous Correlator Spacing (C/A chips)***	***Differential Group Delay***
1	2<BW≤7 MHz	0.045-1.1	0.04-1.2	≤ 600 nsec - N
2	7<BW≤16 MHz	0.045-0.21	0.04-0.235	≤ 150 nsec - N
3	16<BW≤20 MHz	0.045-0.12	0.04-0.15	≤ 150 nsec - N
4	20<BW≤24 MHz	0.080-0.12	0.07-0.13	≤ 150 nsec - N

Note 1: *N is the antenna allocation as defined in RTCA/DO-228 [20]. If the GPS antenna is part of the LAAS equipment, then the combination of the GPS antenna and receiver differential group delay must meet the requirement in the table with N = 0.*

Note 2: *Region 4 is not practical for airborne equipment that also track SBAS ranging signals when implemented using a common receiver front end for receiving the GPS and SBAS signals. This is because the SBAS tracking constraints given in Table 3-9 do not include bandwidths in Region 4 of Table 3-6.*

The instantaneous correlator spacing is defined as the spacing between a particular set of early and late samples of the correlation function. The average correlator spacing is defined as a one-second average of the instantaneous correlator spacing. The average applies over any one-second time frame.

The discriminator (Δ) shall be based upon an average of E-L samples with spacing inside the specified range. Either a coherent or a non-coherent discriminator may be used.

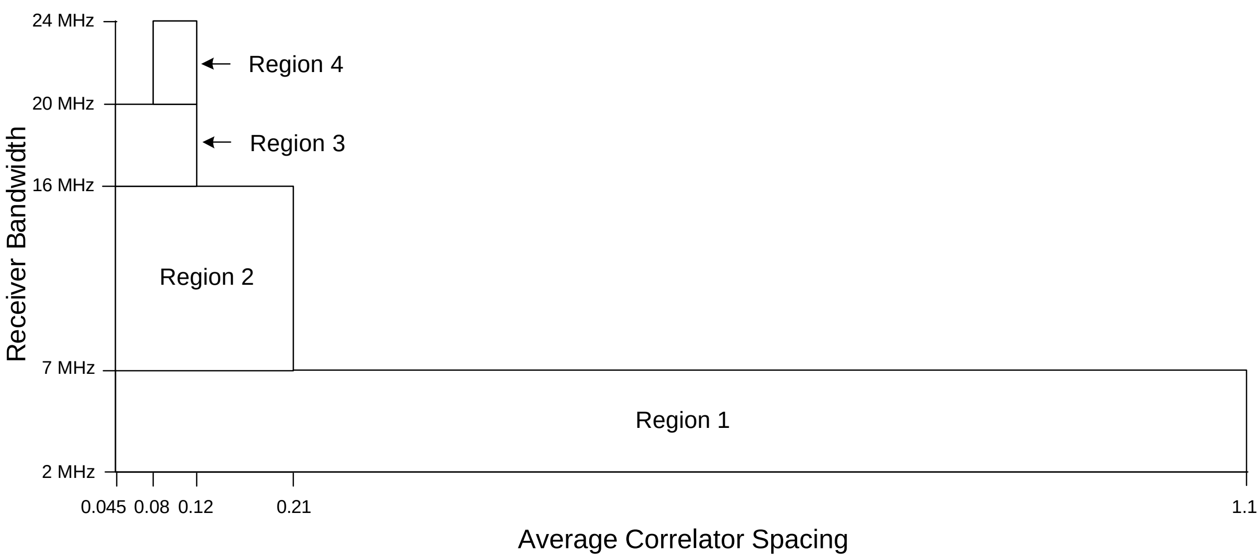


Figure 3-8 Receiver Bandwidth vs. Average Correlator Spacing for E-L Discriminator

For Double Delta (DD) DLL discriminators of the type $\Delta=2\Delta_{d1} - \Delta_{2d1}$ tracking GPS satellites, the pre-correlation bandwidth of the installation, correlator spacings (d_1 and $2d_1$) and the differential group delay shall be within the specified ranges as defined in Table 3-7. Either a coherent or a non-coherent discriminator may be used.

Table 3-7 GPS Tracking Constraints DD DLL Discriminators

Region in Figure 3-9	***3 dB Pre-correlation bandwidth, BW***	***Average Correlator Spacing (d1 and 2d1) [C/A chips]***	***Instantaneous Correlator Spacing (d1 and 2d1) [C/A chips]***	***Differential Group Delay***
1	2<BW≤7 MHz	0.045-0.6	0.04-0.65	≤ 600 nsec - N
2	7<BW≤14 MHz	0.045-0.24	0.04-0.26	≤ 150 nsec - N
3	14<BW≤16 MHz	0.07-0.24	0.06-0.26	≤ 150 nsec - N

Note 3: *N is the antenna allocation as defined in RTCA/DO-228 [20]. If the GPS antenna is part of the LAAS equipment, then the combination of the GPS antenna and receiver differential group delay must meet the requirement in the table with N =0.*

The differential group delay applies to the entire aircraft installed system prior to the correlator, including the antenna. The differential group delay is defined as:

$$\left| \left.\frac{d\phi}{d\omega}\right|_{\omega=2\pi f_c} - \left.\frac{d\phi}{d\omega}\right|_{\omega=2\pi f_o} \right| \qquad \textbf{Equation 3-6}$$

Where:

f_c is the pre-correlation band pass filter center frequency

f_0 is any frequency within the 3 dB bandwidth of the pre-correlation filter

ϕ is the combined phase response of pre-correlation band pass filter and antenna

ω is the frequency in radians/sec; $\omega = 2\pi f$

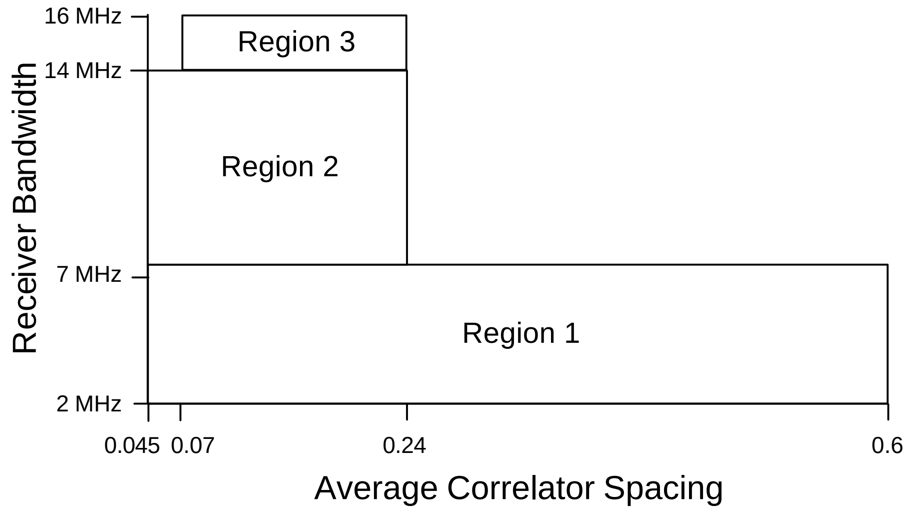


Figure 3-9 Receiver Bandwidth vs. Average Correlator Spacing for DD Discriminator

Note 4: *The technical implementation of the airborne receiver must be constrained to enable the LAAS/JPALS ground system to effectively protect the airborne receiver from possible degradations in the GPS satellite signal. These constraints are described in terms of correlator spacing, receiver bandwidth and receiver differential group delay. The satellite signal degradations considered in developing these constraints are:*

a. Distorted satellite signal causing multiple correlation peaks
b. Correlator peak distortion due to code coherent spurious signals (such as reflected signals or code transition induced wave forms in the satellite)
c. Code coherent spurious signals distorted by RF filter differences
d. Flat correlation peaks causing excessive noise or drift

3.2.2.3.5.3.2 Civil Mode Correlation Peak Validation

The GNSS Receiver shall acquire the main C/A code correlation peak over the full code sequence for each GPS and optional SBAS ranging signal.

For DD DLL discriminators, the equipment shall operate at the correct tracking point corresponding to the strongest peak within the main C/A code correlation peak.

Note: *The requirement to track the strongest peak is based on the effect of potential satellite signal failures on DD DLL discriminators (see ICAO SARPs [27] Annex 10 C.8). It does not apply to E-L DLL discriminators. DD DLL discriminators may demonstrate compliance with this requirement by verifying that the strongest peak is tracked during acquisition and reacquisition. It is not necessary to continually monitor for this condition.*

3.2.2.3.5.3.3 GPS Satellite Acquisition Time

The equipment shall meet the satellite acquisition time requirements of RTCA/DO-229C [21].

The equipment shall meet the GPS satellite acquisition time requirements of CI-GRAM-500 [8] tables 3.3-2.

3.2.2.3.5.3.4 GPS Satellite Reacquisition Time

The equipment shall meet the satellite reacquisition time requirements of RTCA/DO-229C [21].

The equipment shall meet the GPS satellite reacquisition time requirements of CI-GRAM-500 [8] table 3.3-5.

3.2.2.3.5.4 SBAS Signal Processing (optional)

When tracking SBAS satellites (optional) the GNSS Receiver shall meet the following requirements in RTCA/DO-229C [21] identified in Table 3-8 with exceptions as noted.

Table 3-8 GNSS Receiver SBAS Ranging Source Requirements

DO229C Section Reference	***Subject***
2.1.1.3.1	Acquisition and Track
2.1.1.3.2	Demodulation and Forward Error Correction (FEC) Decoding
2.1.1.3.3	WAAS Satellite Pseudorange Determination. Exception: do not apply ionospheric or WAAS tropospheric corrections.
2.1.1.4	WAAS Message Processing Exception: Only WAAS Message Types 9 and 17 are utilized.
2.1.1.4.6	WAAS Message Type 9 - WAAS Satellite Navigation Message
2.1.1.4.7	WAAS Message Type 17 - WAAS Satellite Almanac
2.1.1.8.2	WAAS Satellite Acquisition
2.1.1.9	Satellite Reacquisition Time Exception: These requirements only apply to SBAS satellites.

For the E-L and DD DLL discriminator tracking of SBAS satellites, the pre-correlation bandwidth of the installation, correlator spacing, (d, d1 and 2d1) and the differential group delay shall be within the range as defined in Table 3-9.

Table 3-9 SBAS Ranging Function Tracking Constraints

Region	***3 dB Pre-correlation bandwidth, BW***	***Average Correlator Spacing (d, d1 and 2d1) [C/A chips]***	***Instantaneous Correlator Spacing (d, d1 and 2d1) [C/A chips]***	***Differential Group Delay***
1	2<BW≤7 MHz	0.045-1.1	0.04-1.2	≤ 600 nsec – N
2	7<BW≤20 MHz	0.045-1.1	0.04-1.2	≤ 150 nsec – N

Note: *N is the antenna allocation as defined in RTCA/DO-228 [20]. If the GPS antenna is part of the WAAS equipment, then the combination of the GPS antenna and receiver differential group delay must meet the requirement in the table with N =0.*

For the DD DLL Discriminators, the pre-correlation filter shall roll-off by at least 30 dB per octave in the transition band.

3.2.2.3.5.5 Smoothing

The PAN shall perform carrier smoothing.

In the presence of a code carrier divergence rate of up to 0.018 m/s, the smoothing filter output shall achieve an error less than 0.25 m within 200 seconds after initialization, relative to the steady state response of the following filter:

$$P_{proj} = P_{n-1} + \frac{l}{2p}\left(f_n - f_{n-1}\right) \qquad \textbf{Equation 3-7}$$

$$P_n = a r_n + \left(1 - a\right) P_{proj} \qquad \textbf{Equation 3-8}$$

Where:

P_n is the carrier-smoothed pseudorange in meters,

P_{n-1} is the previous carrier-smoothed pseudorange in meters,

P_{proj} is the projected pseudorange in meters,

r_n is the raw pseudorange measurement in meters (code loop carrier driven, 1st order or higher and with a one sided noise bandwidth greater than or equal to 0.125 Hz)

l is the wavelength in meters,

f_n is the accumulated carrier phase measurement in radians,

f_{n-1} is the previous accumulated carrier phase measurement in radians, and

a is the filter weighting function (a unit less parameter), equal to the sample interval in seconds divided by the time constant of 100 seconds.

Note 1: *The difference between the steady-state response of the smoothing filter implemented in the equipment and the steady-state response of the filter defined above is included in the accuracy requirements of section 3.2.2.3.5.7.*

Note 2: *One acceptable implementation of the airborne smoothing filter is the filter specified above. The filter in the airborne and the filter in the ground station are matched to avoid relative errors induced by ionospheric divergence. Smoothing can be done in parallel with other acquisition processes, making the smoothed pseudoranges available as quickly as possible.*

Note 3: *A method of divergence free carrier smoothing may be defined for dual frequency and/or single frequency GNSS receivers.*

3.2.2.3.5.6 Measurement Quality Monitoring

The satellite signal tracking quality shall be monitored such that the allocated integrity risk due to undetected cycle slip or other undetected measurement faults is within the manufacturer's allocation.

Note 1: *The integrity risk due to undetected cycle slip or other undetected measurement faults is allocated as part of the integrity budget and the continuity impact of these monitors is allocated within the continuity budget (reference section 3.2.2.1.3).*

Note 2: *During an approach, satellite power levels may vary (e.g., due to elevation angles and fading effects that may result in cycle slips). If the satellite is used for positioning and guidance, the loss of the satellite may result in loss of function. The specified interference will further lower the signal-to-noise ratio. Excessive CW interference could cause large pseudorange errors – see Notes 3 and 4 below.*

Note 3: *An example of a monitoring method to maintain integrity at low power and in the presence of normal interference is signal-to-noise ratio monitoring and navigation message parity checking.*

Note 4: *A raw pseudorange measurement that deviates excessively from the projected smoothed pseudorange should be excluded from being used by the smoothing filter. If successive measurements are consistently discarded which would be the case if a carrier or pseudorange step has occurred, the carrier-smoothed pseudorange should not be used. One possible implementation:*

$$if\ |(r_n - P_{proj})| < 10m$$ **Equation 3-9**

Then:

$$P_n = P_{proj} + a(r_n - P_{proj});$$ **Equation 3-10**

Otherwise:

$$P_n = P_{proj}$$ **Equation 3-11**

Note 5: *Additional measurement quality monitoring may be defined.*

3.2.2.3.5.7 Accuracy

The accuracy requirements specified in sections 3.2.2.3.5.7.1 and 3.2.2.3.5.7.2 represent the performance in steady state, including errors such as processing errors, thermal noise, interference, and any residual ionospheric errors caused by a difference between the implemented smoothing filter and the smoothing filter defined in section 3.2.2.3.5.5 in the presence of code-carrier divergence. One can assume the code-carrier divergence is represented by a normal distribution with zero mean and a standard deviation of 0.018 m/s. Steady state operation is defined to be following 360 seconds of continuous operation of the smoothing filter.

Note 1: *Other than the steady-state ionospheric divergence error, the specified accuracy requirements do not include residual signal propagation errors (e.g., multipath or residual tropospheric errors).*

Note 2: *PAN accuracy performance is classified in terms of the Airborne Accuracy Designations.*

Note 3: *The code-carrier divergence rate assumption does not affect equipment that implements the filter defined in section 3.2.2.3.5.5, since the steady-state error from that filter is defined to be zero regardless of the magnitude of the code-carrier divergence (it is the reference filter).*

Note 4: *The Airborne Accuracy Designators referenced in the following sections provide limits for the acceptable accuracy. The actual accuracy values are dependent upon the receiver used.*

Note 5: *This processing applies for a civil mode carrier smooth code processing and may be different for the military mode.*

3.2.2.3.5.7.1 GPS Satellites

The root-mean-squared (RMS) of the total steady-state contribution to the error in the corrected pseudorange for a GPS ranging signal ($RMS_{pr\_air,GPS}$) at the minimum and maximum signal levels (section 3.2.2.3.5.2) shall be as follows.

Minimum signal level for Airborne Accuracy Designator A:

$RMS_{pr\_air,GPS\_C/A} \leq 0.36$ meters

$RMS_{pr\_air,GPS\_L1PY} \leq$ TBD meters

$RMS_{pr\_air,GPS\_L2PY} \leq$ TBD meters

Minimum signal level for Airborne Accuracy Designator B:

$RMS_{pr\_air,GPS\_C/A} \leq 0.15$ meters

$RMS_{pr\_air,GPS\_L1PY} \leq$ TBD meters

$RMS_{pr\_air,GPS\_L2PY} \leq$ TBD meters

Maximum signal level for Airborne Accuracy Designator A:

$RMS_{pr\_air,GPS\_C/A} \leq 0.15$ meters

$RMS_{pr\_air,GPS\_L1PY} \leq$ TBD meters

$RMS_{pr\_air,GPS\_L2PY} \leq$ TBD meters

Maximum signal level for Airborne Accuracy Designator B:

$RMS_{pr\_air,GPS\_C/A} \leq 0.11$ meters

$RMS_{pr\_air,GPS\_L1PY} \leq$ TBD meters

$RMS_{pr\_air,GPS\_L2PY} \leq$ TBD meters

Note: *The Airborne Accuracy Designator characterizes the airborne equipment's contribution to error in the differentially corrected pseudoranges. The Airborne Accuracy Designator consists of a single letter associated with the accuracy of the equipment. Two designators are defined in this document.*

3.2.2.3.5.7.1.1 SL 7 Airborne Accuracy Designator

The GNSS Receiver which supports SL 7 approaches shall meet the accuracy requirements for Airborne Accuracy Designator A or B.

3.2.2.3.5.7.1.2 SL 8 Airborne Accuracy Designator

The GNSS Receiver which supports SL 8 approaches shall meet the accuracy requirements for Airborne Accuracy Designator B.

3.2.2.3.5.7.2 SBAS Satellites (optional)

3.2.2.3.5.7.2.1 SL 7 SBAS Satellites

The RMS of the total steady-state contribution to the error in the corrected pseudorange for an SBAS satellite ($RMS_{pr\_air,SBAS}$) at the minimum and maximum signal levels (section 3.2.2.3.5.2) shall be as follows:

Minimum signal level:

$RMS_{pr\_air,SBAS} \leq 1.8$ meters

Maximum signal level:

$RMS_{pr\_air,SBAS} \leq 1.0$ meters

3.2.2.3.5.7.2.2 SL 8 SBAS Satellites

The use of SBAS as an optional ranging source to support SL 8 is TBD.

3.2.2.3.5.8 Integrity in the Presence of (Abnormal) Interference

The JPALS MAS equipment shall not exceed the limits for outputting misleading information (see 3.2.2.1.3) in the presence of interference.

Note: *This requirement is comprehensive in nature in that it is intended to prevent the output of misleading information under JPALS interference scenarios that could arise.*

3.2.2.3.5.9 Integrity in the Presence of Abnormal Dynamics

The equipment shall not output misleading information during abnormal maneuvers (i.e., the protection limits must bound the navigation errors).

The equipment shall meet the accuracy requirements as specified in section 3.2.2.3.5.7 when the aircraft returns to normal maneuvers from abnormal maneuvers.

Alerts shall function as specified in section 3.2.2.3.10.5.2 during the abnormal maneuvers period.

3.2.2.3.6 Message Processing Function

3.2.2.3.6.1 Civil Sub-Mode

3.2.2.3.6.1.1 SL 7 Civil Sub-Mode Message Processing

The PAN shall be capable of processing ground station message Types 1, 2 and 4 as defined in the JPALS SIS ICD [12].

When processing Type 2 messages, the PAN equipment shall utilize the message length parameter so that it can decode Type 2 messages without additional message blocks, as well as Type 2 messages with one or more additional message blocks.

Note: *This requirement assures compatibility with future as well as current Type 2 message structures. Future data broadcasts may contain multiple additional data blocks; e.g., to provide additional integrity parameters not yet defined in the ICD.*

3.2.2.3.6.1.2 SL 8 Civil Sub-Mode Message Processing

Note 1: *PAN equipment which will be developed to support SL 8 operations or other capabilities may require the means to process additional messages.*

Note 2: *Civil requirements for SL 8 are in development by ICAO.*

3.2.2.3.6.2 Military Sub-Mode

3.2.2.3.6.2.1 SL 7 Military Sub-Mode Message Processing

The PAN shall be capable of processing ground station message Types 1, 2 and 4, as defined in the JPALS SIS ICD [12].

Note: *Additional message types for SL 7 may be defined.*

3.2.2.3.6.2.2 SL 8 Military Sub-Mode Message Processing

The PAN shall be capable of processing ground station message Types 1, 2 and 4, as defined in the JPALS SIS ICD [12].

Note: *Additional message types for SL 8 may be defined.*

3.2.2.3.6.3 VDB Message Validity Check

The PAN shall perform the CRC on all messages used and ignore any message for which the CRC, as defined in the JPALS SIS ICD [12], does not pass.

3.2.2.3.6.4 VDB Message Block Identifier Check

3.2.2.3.6.4.1 Civil Sub-Mode

The PAN shall check the message block identifier (MBI) on all messages and ignore any message for which the MBI does not indicate a "1010 1010" normal LAAS message, as defined in the JPALS SIS ICD [12].

3.2.2.3.6.4.2 Military Sub-Mode

Note: *A Military Sub-Mode MBI may be defined.*

3.2.2.3.7 Corrected Pseudorange

3.2.2.3.7.1 Conditions for Use of Differential Corrections

3.2.2.3.7.1.1 Ephemeris CRC Conditions

The PAN shall verify the ephemeris data received from each GPS ranging source used in the position solution by calculating the ephemeris CRC as defined in the JPALS SIS ICD [12] and comparing it to the Ephemeris CRC value broadcast in the ground station Type 1 message.

The calculated CRC shall be compared to the broadcast CRC within 1 second after receiving a new broadcast IOD for each ranging source used in the position solution.

Note 1: *A new broadcast IOD is one whose value is different from the broadcast IOD last received for the same ranging source.*

The PAN shall cease using any satellite for which the computed and broadcast CRC values fail to match.

Note 2: *The MGS or GBAS will not immediately base its corrections on the satellite clock and ephemeris values in the GPS navigation message that has just changed.*

3.2.2.3.7.1.2 Reference Time Conditions

All satellites used in the position solution shall use corrections with the same reference time as indicated by the modified z-count, which is referred to as a set of differential corrections.

The most recently received set of corrections shall be applied, including pseudorange corrections, range rate corrections, refractivity index, and scale height.

The PAN shall not apply any corrections if the number of measurements field in the Type 1 message indicates that there are no corrections.

Note: *Differential corrections that do not belong to the same set cannot be used in the guidance solution since the clock errors in the pseudorange corrections may be relative to different sets of conditions.*

3.2.2.3.7.1.3 Other Ranging Source Conditions

The differential corrections for a ranging source shall only be applied if all of the following conditions are met.

a. The σ_{pr_gnd} for that ranging source is not set to “1111 1111”.
b. The measurement type is consistent with the airborne measurements being corrected.
c. For GPS satellites, the IOD associated with the differential correction matches the issue of data ephemeris (IODE) associated with the ephemeris used to determine the satellite location and matches the eight least significant bits of the issue of data clock (IODC).
d. The elapsed time from the receipt of the last ground station Type 1 message is less than:
    1. 7.5 seconds for SL 7, or
    2. TBD seconds for SL 8.
e. The difference between current time and the reference time of the corrections (derived from the modified z-count) is less than: 10 seconds.
f. The distance (slant range) between the aircraft and the GBAS reference point is less than the maximum GBAS usable distance, if the maximum GBAS usable distance (D_{max}) is provided in the Type 2 message being used.
g. The difference between the current time and the time of applicability (as derived from the modified z-count in the Type 1 message) for the ephemeris decorrelation parameter (p) associated with that ranging source is less than 120 seconds.

Note 2: *If items (d), (e), and (f) are not met then differential corrections from the ground subsystems should not be applied for any ranging source.*

3.2.2.3.7.2 Application of Differential Corrections

The corrected pseudorange shall be computed as follows and illustrated in Figure 3-10.

$$P_{corrected} = P_n + PRC + RRC * (t - t_{zcount}) + TC + c * (\Delta t_{sv})_{L1} \qquad \textbf{Equation 3-12}$$

Where:

$R_{corrected}$ is the corrected pseudorange (in meters) at the current time,

P_n is the smoothed pseudorange (in meters) at the current time (section 3.2.2.3.5.5),

PRC is the pseudorange correction (in meters) from the message,

RRC is the range rate correction (in meters/second) from the message,

t is the current time (in seconds),

t_{zcount} is the time of applicability of the PRC (in seconds) from the message,

TC is the tropospheric correction (section 3.2.2.3.7.3),

c is the speed of light (in meters/second), and

$(\Delta t_{sv})_{L1}$ is the satellite clock correction, including relativistic correction (sections 3.2.2.3.5.3 and 3.2.2.3.5.4) (in seconds).

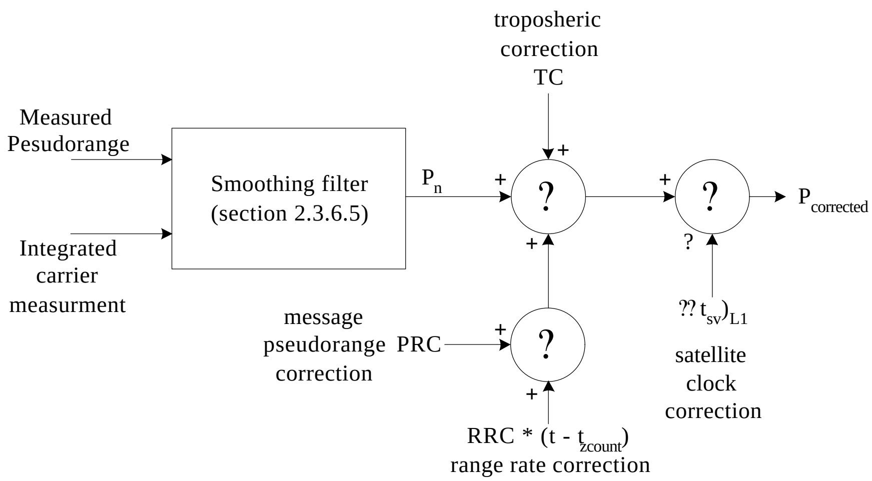


Figure 3-10 Pseudorange Processing

3.2.2.3.7.3 Tropospheric Correction

The PAN shall correct for the differential-troposphere delay error as follows:

$$TC = N_R \; h_0 \frac{10^{-6}}{\sqrt{0.002 + \sin^2(q)}} \left(1 - e^{-\Delta h / h_0}\right) \qquad \textbf{Equation 3-13}$$

Where:

N_R = refractivity index from the ground station Type 2 message (unit less)

Δh = height (meters) of the aircraft above the GBAS reference point

θ = elevation angle of the satellite (degrees)

h_0 = tropospheric scale height (meters) from the ground station Type 2 message or JPALS equivalent

The tropospheric correction as defined above shall not be applied during dual frequency operation.

3.2.2.3.8 LAAS/JPALS Differential Positioning Requirements

The PAN shall compute three-dimensional position using a linearized, weighted least squares solution or its equivalent, based on the set of differential corrections meeting the requirements of section 3.2.2.3.7.1.

Note 1: *Alternate three-dimensional position computations that demonstrate equivalent protection levels and position covariance matrix may be used.*

The position solution shall use Type 1 and Type 2 message data from the same ground station.

The PAN shall only process measurements from satellites for which it has differential corrections (Section 3.2.2.3.7.1) and corresponding airborne pseudorange measurement data available.

A PAN computing three-dimensional position using a weighted least squares solution shall apply differential corrections only if differential corrections are available for four or more satellites.

The position solution shall reflect message data within one second of the output of the last bit of a valid message from the VDB function.

The following method or its equivalent shall be used for computing the position based on the basic linearized GPS measurement model.

The measurement model is

$$\Delta \mathbf{y} = \boldsymbol{G}\,\Delta \boldsymbol{x} + e \qquad \textbf{Equation 3-14}$$

Where:

$\Delta \mathbf{x}$ is the four dimensional delta position/clock vector [three dimensional position (in a standard right-handed coordinate system), and clock] relative to the position/clock vector $\mathbf{x}$ for which the linearization has been made (position in units of meters);

Note 2: *The position can be computed in any three dimensional position coordinate frame but then must be mapped to the runway coordinates without loss of accuracy for protection level computations.*

Δy is an N dimensional residual vector containing the differentially corrected pseudorange measurements (in meters) minus the expected ranging values based on the location of the satellites and the location of the user (x);

N is the number of ranging measurements;

G is the observation matrix consisting of N rows of line of sight vectors from each satellite to x, augmented by a "1" for the clock. Thus the i^{th} row corresponds to the i^{th} satellite in view and is the unit vector from the user position to the satellite position. If the coordinate frame is a local level implementation, then this unit vector can be written in terms of the azimuth angle Az_i and the elevation angle El_i. A positive azimuth angle is defined as counterclockwise about the z-axis from the positive x-axis, and a positive elevation angle is defined as upwards from the x-y plane. This matrix is unit less.

$$\mathbf{G_i} = \begin{bmatrix} -\cos El_i \cos Az_i & -\cos El_i \sin Az_i & -\sin El_i & 1 \end{bmatrix} = \mathbf{i^{th}\ row\ of\ G} \qquad \textbf{Equation 3-15}$$

e is an *N* dimensional vector containing the errors in ***y*** (in meters),

The weighted least squares estimate of the states, $\Delta \hat{\mathbf{x}}$, can be found by:

$$\Delta\hat{\mathbf{x}} = \mathbf{S} \cdot \Delta\mathbf{y}$$ **Equation 3-16**

Where:

$$\mathbf{S} \equiv \left(\mathbf{G}^{\mathbf{T}} \cdot \mathbf{W} \cdot \mathbf{G}\right)^{-1} \cdot \mathbf{G}^{\mathbf{T}} \cdot \mathbf{W}$$ **Equation 3-17**

$$\mathbf{W}^{-1} = \begin{bmatrix} \sigma_1^2 & 0 & \cdots & 0 \\ 0 & \sigma_2^2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \sigma_N^2 \end{bmatrix}$$ **Equation 3-18**

$\mathbf{W}^{-1}$ is the inverse of the measurement uncertainty weighting matrix (units are meters squared)

σ_i is the measurement uncertainty (in meters) associated with satellite *i*.

$$\sigma_i^2 = \sigma_{pr\_gnd}^2[i] + \sigma_{tropo}^2[i] + \sigma_{pr\_air}^2[i] + \sigma_{iono}^2[i]$$ **Equation 3-19**

$\sigma_{pr\_gnd}[i]$ is the total (post correction) measurement uncertainty (in meters) associated with the corresponding differential correction for satellite *i*, as defined in JPALS SIS ICD [12].

$\sigma_{tropo}[i]$ is a residual tropospheric uncertainty (in meters) for satellite *i*, as defined in section 3.2.2.3.11.2.

$\sigma_{pr\_air}[i]$ is the total (post correction) fault-free airborne measurement uncertainty value for satellite *i*, see section 3.2.2.3.11.1.

$\sigma_{iono}[i]$ is a residual ionospheric uncertainty (in meters) for satellite *i*, as defined in section 3.2.2.3.11.3

S is the projection matrix (unit less) that relates the range domain measurements (Δy) to the position domain estimates ($\Delta \hat{\mathbf{x}}$).

The magnitude of the three-dimensional position error induced by discontinuities between sets of differential corrections relative to the weighted least squares position solution or its equivalent, defined above shall be less than 1 cm, where the discontinuity is limited by the range of the differential corrections.

Note 3: *These discontinuities arise from the fact that each set of differential corrections may contain an error common to all corrections in the set, but the error may not be continuous between message updates.*

3.2.2.3.9 PVT Outputs (optional)

The requirements in this section and its subsections apply when outputting PVT based on GBAS differential corrections.

The PAN shall verify that the ground station supports the differentially corrected positioning service before commencing the output of differentially corrected position.

Note 1: *The ground station supports differentially corrected positioning service unless the message type 2 additional data block is not present or the reference station data selector bits are set to '1111 1111'.*

The PAN shall output the following at a rate of at least once per second:

a. differentially-corrected position in latitude, longitude and height above the WGS-84 ellipsoid,

b. three-dimensional velocity (east, north, and up),

c. and time,

d. Vertical Protection Level (*VPL*) and Horizontal Protection Level (*HPL*) per section 3.2.2.3.9.2, and

e. Horizontal figure of merit (HFOM) and vertical figure of merit (VFOM) per section 3.2.2.3.9.3.

Note 2: *A position output at 5 Hz or more may be required to support other applications.*

Note 3: *The time output may be a mark that indicates the time of applicability of the position and velocity. Some applications may require the output of the time in universal time coordinated (UTC). Guidance on velocity and time accuracy performance is given in RTCA/DO-253A [24] Appendix F.*

3.2.2.3.9.1 Message Processing — GBAS ID Selection

The PAN function will only use messages for which the GBAS Identification (ID) in the message block header matches the GBAS ID in the Type 2 message being used to determine the differential PVT outputs. (Reference section 3.2.2.3.8)

3.2.2.3.9.2 Horizontal and Vertical Protection Levels

While providing differentially corrected position outputs, the PAN shall compute the VPL_{POS} and HPL_{POS} of the LAAS/JPALS SIS, for each ground station Type 1 message used in the position solution.

While providing differentially corrected position outputs, the PAN shall output VPL_{POS} and HPL_{POS} for each PVT output.

The PAN shall indicate if VPL_{POS} cannot be calculated.

The PAN shall indicate if HPL_{POS} cannot be calculated.

$$VPL_{\mathrm{POS}} = max\{VPL_{POS\_H0}, VPL_{POS\_H1}, VPB_{POS\_e}\} \qquad \textbf{Equation 3-20}$$

$$HPL_{\mathrm{POS}} = max\{HPL_{H0}, HPL_{H1}, HPB_{e}\}$$ **Equation 3-21**

Note: *VPL_{POS} supports a SIS integrity of less than or equal to 1-2x10-7 per 150 seconds and the HPL_{POS} supports a SIS integrity of less than or equal to 1x10-7 per hour.*

3.2.2.3.9.2.1 H_0 Hypothesis Protection Levels

The *VPL* under the H_0 hypothesis (VPL_{POS_H0}) is:

$$VPL_{POS\_H0} = \frac{K_{ffmd}}{2} VFOM$$ **Equation 3-22**

Where:

K_{ffmd} ≡ reference section 3.2.2.3.10.5.2.1.3

The *HPL* under the H_0 hypothesis (HPL_{H0}) is:

$$HPL_{H0} = 10 d_{major}$$ **Equation 3-23**

Where:

s(),() ≡ elements of the weighted least squares projection matrix S (reference section 3.2.2.3.8) used in the generation of the position for the PVT output

$s^2_{hrz,i} = s^2_{1,i} + s^2_{2,i}$ = projection of the horizontal component for ith ranging source squared.

$$d_{major} = \sqrt{\frac{d_x^2 + d_y^2}{2} \sqrt{\left(\frac{d_x^2 - d_y^2}{2}\right)^2 + d_{xy}^2}}$$ **Equation 3-24**

$d_x^2 = \sum_{i=1}^{N} s_{1,i}^2 s_i^2$ = variance of model distribution that over bounds the true error distribution in the “1” axis **Equation 3-25**

$d_y^2 = \sum_{i=1}^{N} s_{2,i}^2 s_i^2$ = variance of model distribution that over bounds the true error distribution in the “2” axis **Equation 3-26**

$d_{xy} = \sum_{i=1}^{N} s_{1,i} s_{2,i} s_i^2$ = covariance of the model distribution in the “1” and “2” axes

Equation 3-27

σ_i ≡ weightings used in the least squares solution (reference section 3.2.2.3.8)

3.2.2.3.9.2.1.1 VFOM

VFOM is:

$$VFOM = 2\sqrt{\sum_{i=1}^{N} s_{vert,i}^{2} s_{i}^{2}} \qquad \textbf{Equation 3-28}$$

Where:

s(),() ≡ elements of the weighted least squares projection matrix S (reference section 3.2.2.3.8) used in the generation of the position for the PVT output

$s_{vert,i}$ = projection of the local vertical component for the ith ranging source

σ_i ≡ weightings used in the least squares solution (reference section 3.2.2.3.8)

3.2.2.3.9.2.1.2 HFOM

HFOM is:

$$HFOM = 2d_{major} \qquad \textbf{Equation 3-29}$$

3.2.2.3.9.2.2 H_1 Hypothesis Protection Levels

The protection levels under the H_1 hypothesis are:

$$VPL_{POS\_H1} = \max\left[VPL_{POS\_H1}[j]\right] \qquad \textbf{Equation 3-30}$$

$$HPL_{H1} = \max\left[HPL_{H1}[j]\right] \qquad \textbf{Equation 3-31}$$

Where:

$VPL_{POS\_H1}[j]$ for all j (1 to MAX { M[i] }) as follows:

$$VPL_{POS\_H1}[j] = \left|B_{j\_POS\_vert}\right| + K_{md\_POS\_vert} s_{POS\_vert\_H1} \qquad \textbf{Equation 3-32}$$

$$B_{j\_POS\_vert} = \sum_{i=1}^{N} s_{3,i} B[i, j] \qquad \textbf{Equation 3-33}$$

$$s_{POS\_vert\_H1}^{2} = \sum_{i=1}^{N} s_{3,i}^{2} s_{i\_H1}^{2} \qquad \textbf{Equation 3-34}$$

$HPL_{H1}[j]$ for all j (1 to MAX { M[i] }) as follows:

$$HPL_{H1}[j] = \left|B_{j\_H}\right| + K_{md\_POS\_hrz} d_{major\_H1} \qquad \textbf{Equation 3-35}$$

$$B_{j\_H} = \sqrt{\left(\sum_{i=1}^{N} s_{1,i} B[i,j]\right)^2 + \left(\sum_{i=1}^{N} s_{2,i} B[i,j]\right)^2}$$ **Equation 3-36**

$$d_{major\_H1} = \sqrt{\frac{d\_H1_x^2 + d\_H1_y^2}{2} \sqrt{\left(\frac{d\_H1_x^2 - d\_H1_y^2}{2}\right)^2 + d\_H1_{xy}^2}}$$ **Equation 3-37**

$d\_H1_x^2 = \sum_{i=1}^{N} s_{1,i}^2 s_{i\_H1}^{2}$ = variance of model distribution that over bounds the true error distribution in the “1” axis **Equation 3-38**

$d\_H1_y^2 = \sum_{i=1}^{N} s_{2,i}^2 s_{i\_H1}^{2}$ = variance of model distribution that over bounds the true error distribution in the “2” axis **Equation 3-39**

$d\_H1_{xy}^2 = \sum_{i=1}^{N} s_{1,i} s_{2,i} s_{i\_H1}^{2}$ = covariance of the model distribution in the “1” and “2” axes

Equation 3-40

$\sigma^2_{i\_H1}$ ≡ reference section 3.2.2.3.10.5.2.1.3

$K_{md\_POS\_vert} = K_{md}$ ≡ reference section 3.2.2.3.10.5.2.1.3

$K_{md\_POS\_hrz}$ ≡ 5.3 (unit less)

M[i] = number of ground subsystem reference receivers whose pseudorange measurement was used to determine the differential correction for the ith ranging source used in the position solution

B[i,j] = the B value (in meters) for the ith ranging source and jth reference receiver as indicated in the Type 1 Message

Note: *The PAN applies the value of zero for each of B value set to the bit pattern “10000000”. This bit pattern indicates that the measurement is not available.*
Optionally, $s_{Apr\_vert,i}$ can be substituted for $s_{3,i}$ in calculating vertical protection level (VPL_{POS}) and VFOM for the position when an approach is selected since it is more conservative.
The system allocation for integrity to support RNAV applications has not been completed. This definition of HPL is intended to minimize the allocation necessary for the H_0 hypothesis.

3.2.2.3.9.2.3 Ephemeris Error Bounds

The vertical ephemeris error position bounds (VPB_{POS_e}) and horizontal ephemeris error position bounds (HPB_e) are given by:

$$VPB_{POS\_e} = \max\left(VPB_{POS\_e}[k]\right)$$ **Equation 3-41**

$$HPB_e = \max\left(HPB_e[k]\right) \qquad \textbf{Equation 3-42}$$

Where:

$VPB_{POS\_e}[k]$ is the vertical ephemeris error position bound for the k^th GPS ranging source used in the position solution, where $VPB_{POS\_e}[k]$ is computed for all GPS ranging sources used in the position solution:

$$VPB_{POS\_e}[k] = \left|s_{vert,k}\right| x_{air} P_k + K_{md\_e\_POS\_vert} \sqrt{\sum_{i=1}^{N} s_{vert,i}^2 \sigma_i^2} \qquad \textbf{Equation 3-43}$$

P_k = ephemeris decorrelation parameter for ranging source k broadcast in the Type 1 message

x_{air} = distance (slant range) between the aircraft and the GBAS reference point (in meters)

$K_{md\_e\_POS\_vert} = K_{md\_e\_CAT1}$ (reference section 3.2.2.3.10.5.2.1.4)

$HPB_e[k]$ is the horizontal ephemeris error position bound for the k^th GPS ranging source used in the position solution, where $HPB_e[k]$ is computed for all GPS ranging sources used in the position solution:

$$HPB_e[k] = \left|s_{hrz,k}\right| x_{air} P_k + K_{md\_e\_POS\_hrz} d_{major} \qquad \textbf{Equation 3-44}$$

$K_{md\_e\_POS\_hrz} = K_{md\_e\_POS}$ = the broadcast multiplier for computation of the ephemeris error position bound for the GBAS positioning service derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite (unit less)

Note 1: *The ephemeris error position bounds are computed only for GPS satellites used in the position solution (k index) and not for other types of ranging sources (SBAS satellites or pseudolites) that are not subject to undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).*

Note 2: *Optionally, $s_{Apr\_vert,i}$ can be substituted for $s_{vert,i}$ in calculating vertical protection level (VPL_{POS}), vertical position bound for ephemeris (VPB_{POS_e}), and VFOM for the position when an approach is selected since it is more conservative.*

3.2.2.3.9.3 Figures of Merit

The PAN shall output HFOM (3.2.2.3.9.2.1.2) and VFOM (3.2.2.3.9.2.1.1) while providing differentially corrected position.

The equipment shall indicate if HFOM cannot be calculated.

The equipment shall indicate if VFOM cannot be calculated.

3.2.2.3.9.4 PVT Output Latency

When PVT is output, the latency of the differentially corrected position, velocity, and time outputs, and their associated protection level and figure of merit outputs, shall be less than or equal to 500 milliseconds.

Note: *Output latency is defined as the interval between the time of the measurement and the time of applicability of the position.*

When PVT is output, data defining the differentially corrected position shall be output prior to 200 milliseconds after the time of applicability.

3.2.2.3.10 Precision Approach Guidance Outputs

3.2.2.3.10.1 Message Processing

3.2.2.3.10.1.1 FAS Data Block Selection and Confirmation

The PAN shall select from the ground station Type 4 message(s) the FAS data set corresponding to the selected approach.

The PAN shall validate the CRC for the selected FAS data block and only use it if the FAS data block CRC, as defined in the JPALS ICD, passes.

The PAN shall output the corresponding Reference Path Identifier for the validated FAS data block.

3.2.2.3.10.1.2 Reference Station Selection

When a FAS data block has been selected, the PAN shall only use messages for which the Reference Station Identification matches the GBAS ID in the ground station Type 4 message containing the selected FAS data block.

3.2.2.3.10.2 Precision Approach Region

The Precision Approach Region (PAR) associated with an approach procedure is the region defined by the following conditions (see Figure 3-11):

a. Distance to the LTP/FTP in the horizontal plane < 10 nmi;
b. Bearing to the indicated end of the runway is within ± 90 degrees of the FAS bearing;
c. Proportional lateral deviation is within twice full scale; and
d. Aircraft position is below twice the full-scale fly down on the proportional vertical deviations or below a height of 200 feet above the LTP/FTP.

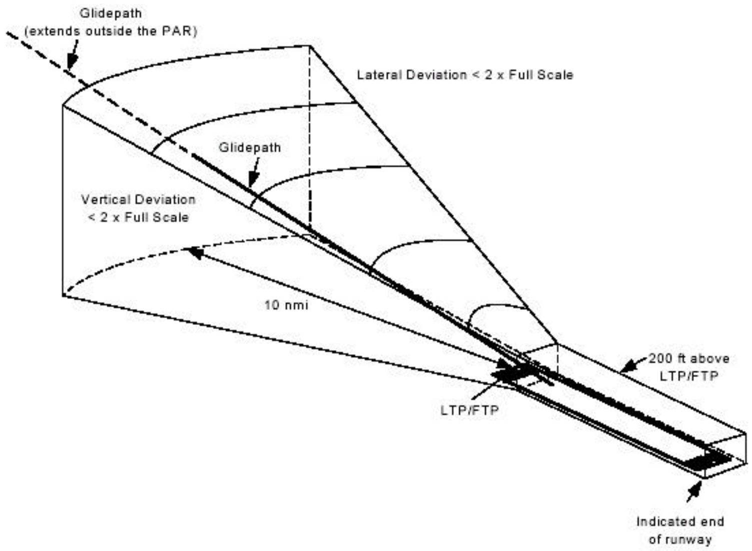


Figure 3-11 Precision Approach Region

Note 1: *The indicated end of the runway, or stop end of the runway, is defined by the parameters in the FAS data block associated with the selected approach by the parameter's length offset and the flight path alignment point (FPAP) location.*

Note 2: *The twice full-scale proportional lateral deviations between the LTP/FTP and the indicated end of the runway may be rectilinear or angular.*

3.2.2.3.10.3 Approach Status Verification

The PAN shall evaluate the "FAS vertical and lateral alert limit/approach status" fields in ground station message type 4:

a. for each selected FAS data block received when the aircraft is outside the PAR; or
b. once before outputting valid deviation if the approach is selected while the aircraft is inside the PAR.

After the aircraft is inside the PAR, and once the FAS vertical and lateral alert limit/approach status field has been verified at least once, the PAN shall stop checking the FAS vertical and lateral limit/approach status field.

When the vertical and lateral alert limit/approach status fields are evaluated, the PAN shall within 1 second:

a. Indicate the vertical deviations are invalid if the FAS vertical alert limit/approach status field is coded as "1111 1111" in the most recently received FAS block associated with the selected approach.
b. Indicate the vertical and lateral deviations are invalid if the FAS lateral alert limit/approach status field is coded as "1111 1111" in the most recently received FAS block associated with the selected approach.

3.2.2.3.10.4 Ground Continuity Integrity Designator (GCID) Conditions

The PAN shall only output valid deviations if it verifies that the GCID in the ground station Type 2 message is 1, 2, 3 or 4, as defined in the JPALS SIS ICD [12].

The PAN shall continually verify the GCID and cease applying the LAAS/JPALS differential corrections within 1 second of receiving a ground station Type 2 message with GCID set to other than 1, 2, 3 or 4 when outside the PAR.

The PAN shall disregard any changes in the GCID when inside the PAR.

3.2.2.3.10.5 Outputs

3.2.2.3.10.5.1 Deviations

The deviation definitions are based on FAS data as defined in the JPALS SIS ICD [12], illustrated in Figure 3-12, and described in RTCA/DO-253A [24] Appendix C. Deviations are defined for a guidance reference point (GRP) on the aircraft. The GRP for lateral and vertical deviations may be different. The GRP may be the phase-center of the GPS antenna, a fixed offset (in the along-track/vertical axes), or a separate point referenced to the aircraft.

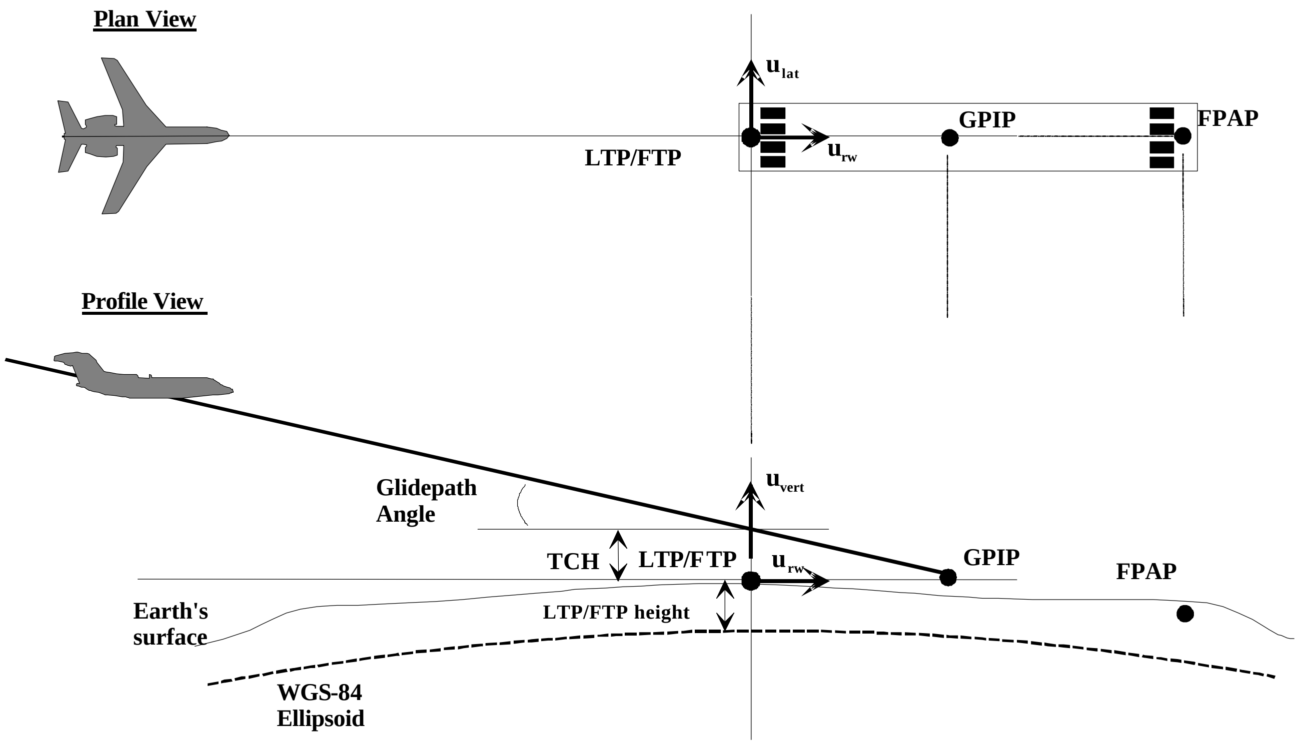


Figure 3-12 Final Approach Segment Definition

The PAN shall provide lateral deviation data meeting the requirements of section 3.2.2.3.10.5.1.1.

The PAN shall provide vertical deviation data meeting the requirements of section 3.2.2.3.10.5.1.2 only when:

a. The computed position is within the vertical guidance validity region, (section 3.2.2.3.10.5.1.2.1)
b. No Vertical Integrity Alerts are activated (section 3.2.2.3.10.5.2)
c. The FAS vertical alert limit/approach status field is not coded as “1111 1111” in the most recently received FAS block associated with the selected approach.

The PAN shall initially output precision approach guidance information within 2 seconds following receipt of the necessary valid messages supporting the selected approach, provided all other necessary conditions are met (e.g., sections 3.2.2.3.7.1 and 3.2.2.3.10.3).

Note: *The PAN will need to store all FAS data blocks from the selected reference station in order to provide approach guidance information within two seconds of selection of another approach from the same station.*

The electrical output shall have the characteristics shown in Table 3-10 if the PAN is providing non-numeric (analog) deviations,

Table 3-10 Non-Numeric Electrical Output Requirements

	Requirement (% of Full-Scale)
Resolution of Electrical Output	1%
Accuracy of Centered Display	3%
Linearity of Display or Electrical Output	5%

3.2.2.3.10.5.1.1 Lateral Deviations

The rectilinear lateral deviation shall be defined as the distance between the aircraft GRP and closest point on the lateral deviation reference plane (positive left) where:

a. The lateral deviation reference plane is the plane that contains the LTP/FTP vertical direction vector and the FPAP.
b. The vertical direction vector is the vector that passes through the LTP/FTP and is normal to the WGS-84 ellipsoid at the LTP/FTP.
c. The GNSS Landing System (GLS) azimuth reference point (GARP) is the point that lies in the horizontal plane containing the LTP/FTP and is 305 meters beyond the point where the vertical projection of the FPAP intersects this plane (See RTCA/DO-253A [24] Appendix C).

The angular lateral deviation shall be defined as the angle whose tangent is the ratio of the rectilinear lateral deviation and the along-track distance between the aircraft and the GARP.

The PAN shall output the lateral deviations according to the following full-scale deflection (FSD) Regions (see Figure 3-13) defined as follows:

Region 1: When the angular lateral deviation is within the range of ± 90 deg and the bearing to the LTP/FTP is within ± 90 deg of the FAS bearing, the angular lateral deviation output scaled in degrees to difference in depth of modulation (DDM) is determined according to:

$$Lateral\ DDM = \frac{Angular\ Deviation}{\tan^{-1}\left(\dfrac{Course\ Width\ At\ Threshold}{GARP\ to\ LTP/FTP\ Distance}\right)} \bullet 0.155$$ **Equation 3-45**

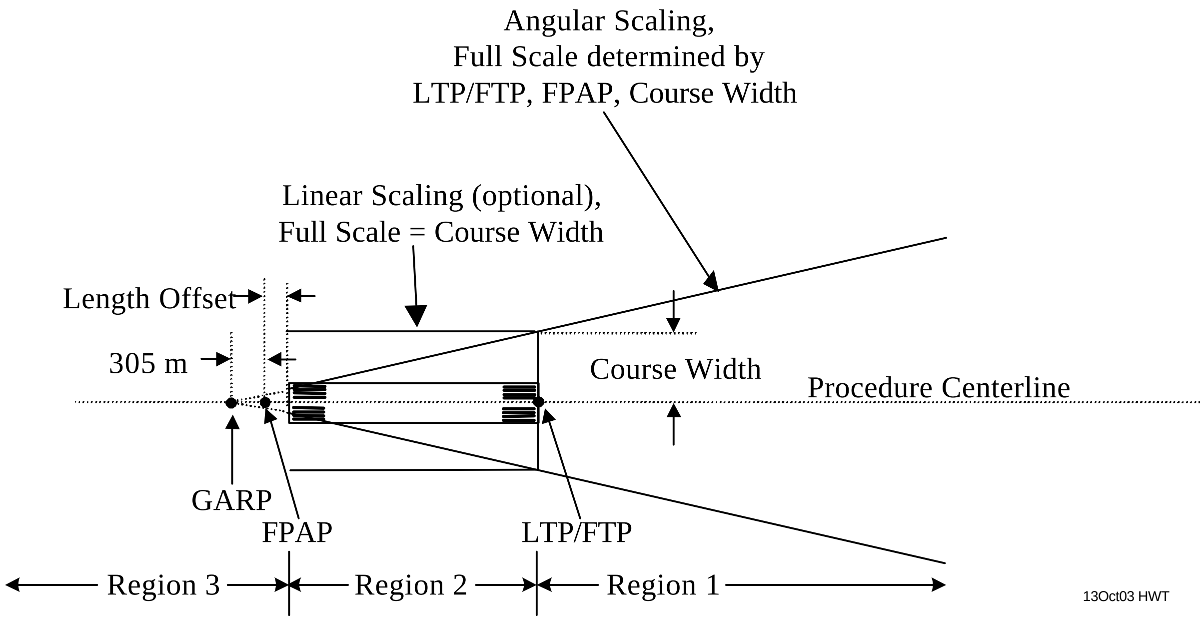


Figure 3-13 Full-Scale Deflection Regions for Lateral Deviation

Region 2: When the bearing to the end of the runway is within the range of ± 90 deg of the FAS bearing and the bearing to the LTP/FTP is outside the range of ± 90 deg of the FAS bearing, the deviation may be a rectilinear lateral deviation as a difference in depth of modulation (DDM) where Course Width At Threshold from the FAS data block equals 0.155 DDM, or the deviation may be an angular deviation as a DDM where the scaling is the same as that in Region 1.

Region 3: When the bearing to the end of the runway is outside the range of ± 90 deg from the FAS bearing, the lateral deviation as a DDM where 0.3 nm equals 0.155 DDM.

Positive lateral deviations shall correspond to aircraft positions to the left of the lateral deviation reference plane, as observed from the LTP/FTP facing toward the FPAP.

The PAN shall provide proportional lateral deviation to at least twice the FSD and outside this region, the maximum output value shall be indicated.

Note: *Compatibility with ILS display systems can be achieved by converting the proportional lateral deviation to mA (DDM) based upon FSD at 150 mA (0.155 DDM). For aircraft positions beyond twice the FSD, the maximum output value is not limited except as constrained by the input limitations of the display instrumentation.*

3.2.2.3.10.5.1.2 Vertical Deviations

The rectilinear vertical deviation shall be defined as the distance between the aircraft and the vertical deviation reference surface (positive above) where:

a. The horizontal reference plane is the plane that contains the LTP/FTP and is normal to LTP/FTP vertical direction vector.
b. The glide path intercept point (GPIP) is the intersection of the glide path with the horizontal reference plane.
c. The vertical deviation reference surface is one of the following:
   1. The conical surface containing the FAS whose apex is at the GPIP and whose axis of symmetry is parallel to the LTP/FTP vertical direction vector;
   2. A conical surface as described in 1 above, but whose apex is offset up to 150 m from the GPIP in a direction normal to the lateral deviation reference plane; or
   3. A hyperbolic surface that asymptotically approaches the conical surface described in 1 above, whose minimum height is not more than 8 m above the GPIP.
d. The origin is the point on the vertical deviation reference surface with the minimum height above the GPIP (for 1 and 2 above, this point is the apex of the cone).

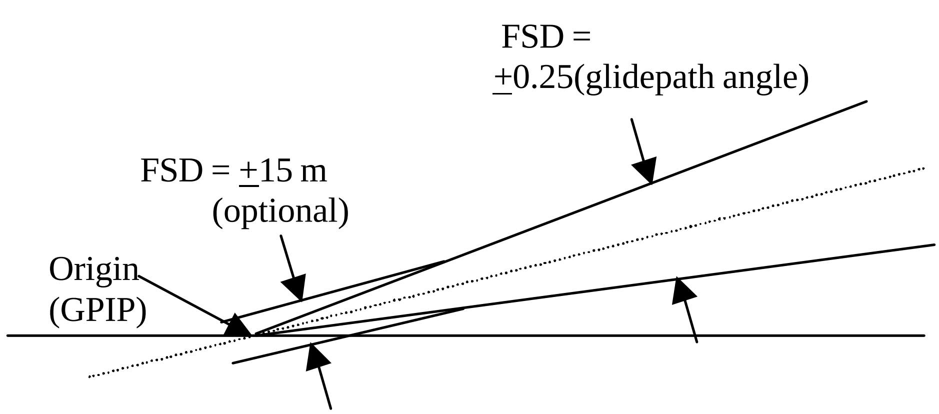
The vertical deviation shall be defined as the angle whose sine is the ratio of the rectilinear vertical deviation and the distance between the aircraft and the GLS elevation reference point (GERP).

Note 1: *The GERP may be at the GPIP or laterally offset from the GPIP by a fixed GERP offset value of 150 m (see RTCA/DO-253A [24] figure C-3).*

The final approach segment vertical deviation is defined to be proportional to the angle (α_{vert}) measured at the origin between the aircraft and the point on the vertical deviation reference surface that is closest to the aircraft, with FSD for a vertical error of:

$$a_{vert,FS} = \pm 0.25(\text{FAS glidepath angle})$$ **Equation 3-46**

The proportional vertical deviation shall be as follows, where the full-scale deflection for the deviation is illustrated in Figure 3-14:



Note: Offset conical vertical deviation reference surface and hyperboloid surface are not depicted.

Figure 3-14 Full-Scale Deflection for Vertical Deviation

a. At a distance greater than or equal to $\frac{150m}{\tan(a_{FS,vert})}$ to the origin, the deviation shall be linear (i.e., proportional to the distance from the aircraft GRP to the closest point on the vertical deviation reference surface) with FSD for a vertical error of 150 m; the final approach segment vertical deviation;

b. Closer than $\frac{15m}{\tan(a_{FS,vert})}$ to the origin, the deviation shall be either the final approach segment vertical deviation or linear (i.e., proportional to the distance from the aircraft GRP to the closest point on the vertical deviation reference surface) with FSD for a vertical error of ±15 m.

Note 2: *Compatibility with ILS display systems can be achieved by converting the vertical deviation to mA (DDM) based upon FSD at 150 mA (0.175 DDM). For aircraft positions beyond twice the FSD, the maximum output value is not limited except as constrained by the input limitations of the display instrumentation.*

The PAN shall provide proportional vertical deviation to at least twice the FSD.

The vertical deviation shall be set to the maximum negative (i.e., fly-up) value when outside the vertical guidance validity region (section 3.2.2.3.10.5.1.2.1).

3.2.2.3.10.5.1.2.1 Vertical Guidance Validity Region

Vertical deviations shall be flagged as invalid if:

a. The lateral position of the aircraft is outside of a ±35 degree wedge with origin at the GARP, centered on the FAS; or
b. The aircraft is not on the approach side of the GPIP.

3.2.2.3.10.5.1.3 Deviation Output Rate and Latency

The PAN shall compute lateral and vertical deviation at least 5 times per second, when deviation data are provided.

Note 1: *A 5-per-second update rate may not be sufficient for all aircraft installations.*

The PAN shall compute deviations from dynamically independent position updates.

Note 2: *A dynamically independent position update is one that captures aircraft acceleration that occurs after the previous position computation. Position updates developed by extrapolating from previous position and velocity computations are not dynamically independent.*

The PAN shall output lateral and vertical deviation labels at a nominal rate of at least 16 times per second.

The overall latency shall not exceed 400 msec for inputs with frequency content in the range of zero to 1 radian per second.

Note 3: *Overall latency is defined as the total delay between normal maneuver dynamic inputs (section 3.2.2.3.2) and the completion of transmission of the deviation output reflecting the inputs.*

Note 4: *This metric includes the effects of tracking-loop dynamic response, computation rate, computational latency, and 200 msec allocated to the GNSS Receiver.*

3.2.2.3.10.5.1.4 Missed Approach Guidance (optional)

If the PAN provides missed approach guidance, it shall sequence to outputting lateral deviation with linear scaling such that the FSD for a cross-track error is ±0.3 nautical mile full scale deflection referenced to the extended approach centerline. The vertical deviations shall be output as invalid for the missed approach segment.

The PAN shall sequence to missed approach guidance based on an external input commanding missed approach.

The PAN shall transition automatically sequence to missed approach guidance when all of following conditions are satisfied:

a. The computed aircraft position passes the LTP/FTP (i.e., bearing to the LTP/FTP is more than ±90 deg from the FAS bearing),
b. The GRP height is greater than 200 feet above the LTP/FTP, and
c. The proportional vertical deviation is full-scale fly down.

Note: *In many installations, LAAS/JPALS equipment will be complemented with RNAV equipment that will provide the missed approach guidance for the missed approach segment. For these aircraft, it is not required that the LAAS equipment output missed approach guidance.*

3.2.2.3.10.5.2 Alerts

3.2.2.3.10.5.2.1 Loss of Approach Guidance

The PAN shall provide an indication when the navigation system is no longer adequate to conduct or continue the precision approach.

The lateral and vertical deviations outputs shall be invalidated within one second of the onset of any of the following conditions:

a. The absence of power (loss of function is an acceptable indicator);
b. Probable equipment malfunction or failure.

The lateral and vertical deviation outputs shall be invalidated within 0.4 seconds from the onset of any of the following conditions:

a. The lateral protection level (section 3.2.2.3.10.5.2.1.3) or the Lateral Ephemeris Error Position Bound (section 3.2.2.3.10.5.2.1.4) exceeds the lateral alert limit (section 3.2.2.3.10.5.2.1.1);
b. For SL 7 the elapsed time from the receipt of the last Type 1 message is equal to or greater than 3.5 seconds and the aircraft is within the PAR;
c. For SL 8 the elapsed time from the receipt of the last Type 1 message is equal to or greater than 1.5 seconds and the aircraft is within the PAR;

d. For SL 7 the difference between the current time and the reference time of the corrections (derived from the modified z-count) is equal to or greater than 6 seconds and the aircraft is within the PAR.
e. For SL 8 the difference between the current time and the reference time of the corrections (derived from the modified z-count) is equal to or greater than TBD seconds and the aircraft is within the PAR.

The vertical deviation output shall be invalidated within 0.4 seconds from the time the vertical protection level (section 3.2.2.3.10.5.2.1.3) or the Vertical Ephemeris Error Position Bound (section 3.2.2.3.10.5.2.1.4) exceeds the vertical alert limit (section 3.2.2.3.10.5.2.1.2).

3.2.2.3.10.5.2.1.1 Lateral Alert Limits

When the computed position is inside the PAR (section 3.2.2.3.10.2) and the selected approach is SL 7, the lateral alert limit shall be as defined in Table 3-11.

When the computed position is inside the PAR (section 3.2.2.3.10.2) and the selected approach is SL 8, the lateral alert limit shall be as defined in Table 3-12.

When the approach has been selected, and the computed position is outside of the PAR, the lateral alert limit shall be the sum of Final Approach Segment Lateral Alert Limit (FASLAL) and 29.15 meters.

Table 3-11 SL 7 Lateral Alert Limit

Lateral alert limit (meters)	***Horizontal distance of aircraft position to the LTP/FTP (D) (meters)***
FASLAL (see Note)	-(Distance from LTP/FTP to stop-end of runway) < D ≤ 873
0.0044D+FASLAL-3.85	873 < D ≤ 7500
FASLAL+29.15	D > 7500

Table 3-12 SL 8 Lateral Alert Limit

Lateral alert limit (meters)	***Horizontal distance of aircraft position to the LTP/FTP (D) (meters)***
FASLAL (see Note)	-(Distance from LTP/FTP to stop-end of runway) < D ≤ 291
0.0020875*D+FASLAL-0.6	291 < D ≤ 7212
FASLAL+14.5	D > 7212

Note: *FASLAL, as defined in JPALS SIS ICD [12], is the Lateral Alert Limit for the selected approach, see section 3.2.2.3.10.1.1.*

3.2.2.3.10.5.2.1.2 Vertical Alert Limits

When the computed position is inside the PAR (section 3.2.2.3.10.2) and the selected approach is SL 7, the vertical alert limit shall be as defined in Table 3-13.

When the computed position is inside the PAR (section 3.2.2.3.10.2) and the selected approach is SL 8, the vertical alert limit shall be as defined in Table 3-14.

When the approach has been selected, and the computed position is outside of the PAR, the lateral alert limit shall be the sum of Final Approach Segment Vertical Alert Limit (FASVAL) and 33.35 meters.

Table 3-13 SL 7 Vertical Alert Limit

Vertical alert limit (meters)	***H_p (meters) (see Note 1)***
FASVAL (see Note 2)	$H_p \le 60.96$
$0.095965H_p$+FASVAL-5.85	$60.96 < H_p \le 408.432$
FASVAL+33.35	$H_p > 408.432$

Table 3-14 SL 8 Vertical Alert Limit

Vertical alert limit (meters)	***H_p (meters) (see Note 1)***
FASVAL (see Note 2)	$H_p \le 30.48$
$0.095965H_p$+FASVAL-.2.9	$30.48 < H_p \le 393.192$
FASVAL+33.35	$H_p > 393.192$

Note 1: *The product of sin(GPA) [where GPA is Glide Path Angle] and the slant-range distance from the aircraft position to the GPIP.*

Note 2: *FASVAL, as defined in RTCA/DO-246B [23], is the Vertical Alert Limit for the selected approach, (see section 3.2.2.3.3).*

3.2.2.3.10.5.2.1.3 Lateral and Vertical Protection Levels

The PAN shall compute the Lateral and Vertical Protection Levels of the LAAS/JPALS SIS, for each ground station Type 1 message used in the navigation solution, relative to the selected approach segment (LPL_{Apr} and VPL_{Apr}) by computing the lateral and vertical protection levels for the H0 and H1 hypothesis (VPL_{Apr_H0}, LPL_{Apr_H0}, VPL_{Apr_H1}, and LPL_{Apr_H1}).

$$LPL_{Apr} = \max[LPL_{Apr\_H0}, LPL_{Apr\_H1}] \qquad \textbf{Equation 3-47}$$

$$VPL_{Apr} = \max[VPL_{Apr\_H0}, VPL_{Apr\_H1}] \qquad \textbf{Equation 3-48}$$

The protection levels under the H0 hypothesis are computed as follows:

$$VPL_{Apr\_H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_ert,i}\, s_i^2} \qquad \textbf{Equation 3-49}$$

$$LPL_{Apr\_H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s^2_{lat,i}\, s_i^2} \qquad \textbf{Equation 3-50}$$

Where:

K_{ffmd} = multiplier which determines the probability of fault-free missed detection: K_{ffmd} is a function of the number of differential corrections being used in the navigation solution and service level of the selected approach, as defined in Table 3-15.

Table 3-15 Fault Free Missed Detection Multipliers

K_{ffmd}			
Service Level	M_{ffmd}=2	M_{ffmd}=3	M_{ffmd}=4
7	5.762	5.810	5.847
8	6.598	6.641	6.673

M[i] = number of ground subsystem reference receivers whose pseudorange measurement was used to determine the differential correction for the i^{th} ranging source used in the navigation solution. This number is determined from the B-values in the ground station Type 1 message (reference JPALS SIS ICD [12]), in the received VDB message.

M_{ffmd} = the maximum M[i]

s(),() ≡ elements of the weighted least squares projection matrix S (reference section 3.2.2.3.8) used in the generation of the precision approach guidance outputs (unit less).

The navigation solution is mapped to a runway reference local level frame. This reference frame is defined such that the x is along-track, positive forward, y is cross-track positive left in the local level tangent plane at the LTP/FTP, and z is the positive up and orthogonal to this local level tangent plane.

$s_{1,i}$ =, the projection of the x-component for the ith satellite

$s_{2,i}$ = the projection of the y-component for the ith satellite

$s_{3,i}$ = the projection of the z-component for the ith satellite

$s_{Apr\_vert,i} = s_{3,i} + s_{1,i} * \tan \theta_{GPA}$ = projection of the vertical component and translation of the along track errors into the vertical for i^{th} ranging source.

Note 2: *The second term in $s_{Apr\_vert,i}$ accounts for the effect of uncertainty in the along-track position on the error in the vertical guidance output.*

$s_{Apr\_lat,i} = s_{2,i}$ = projection of the lateral component for i^{th} ranging source

$\theta_{\theta GPA}$ = GPA for the final approach path

N = number of ranging sources used in the position solution

σ_i ≡ reference section 3.2.2.3.8

i = ranging source index.

The protection levels under the H1 hypothesis are computed as follows:

$$VPL_{Apr\_H1} = \max\left[VPL_{Apr\_H1}[j]\right]$$

$$LPL_{Apr\_H1} = \max\lfloor LPL_{Apr\_H1}[j] \rfloor$$ **Equation 3-51**

Where:

$VPL_{Apr\_H1}[j]$ and $LPL_{Apr\_H1}[j]$ for all j (1 to MAX { M[i] }) as follows:

$$VPL_{Apr\_H1}[j] = \left|B_{j\_Apr\_vert}\right| + K_{md} s_{Apr\_vert\_H1}$$ **Equation 3-52**

$$LPL_{Apr\_H1}[j] = \left|B_{j\_Apr\_lat}\right| + K_{md} s_{Apr\_lat\_H1}$$ **Equation 3-53**

j = ground subsystem reference receiver index

K_{md} = multiplier (unit less) which determines the probability of missed detection given that the ground subsystem is faulted: K_{md} is a function of the number of differential corrections being used in the navigation solution and service level of the selected approach, as defined in Table 3-16.

Table 3-16 Missed Detection Multipliers

K_{md}			
Service Level	***M_{md}=2***	***M_{md}=3***	***M_{md}=4***
7	2.935	2.898	2.878
8	4.305	4.279	4.265

M_{md} = the minimum M[i]

B[i,j] = reference section 3.2.2.3.9.2

Note 4: *The PAN applies the value of zero for each of B value set to the bit pattern "1000 0000." This bit pattern indicates that the measurement is not available.*

$$B_{j\_Apr\_vert} = \sum_{i=1}^{N} s_{Apr\_vert,i} B[i, j]$$ **Equation 3-54**

$$B_{j\_Apr\_lat} = \sum_{i=1}^{N} s_{lat,i} B[i, j]$$ **Equation 3-55**

$$s^2_{i\_H1} = \left(\frac{M[i]}{U[i]}\right) s^2_{pr\_gnd}[i] + s^2_{tropo}[i] + s^2_{pr\_air}[i] + s^2_{iono}[i]$$ **Equation 3-56**

U[*i*] = number of ground subsystem reference receivers whose pseudorange measurements were used to determine the differential correction for the i^{th} ranging source used in the navigation solution, not counting the j^{th} reference receiver.

$$s^2_{Apr\_vert\_H1} = \sum_{i=1}^{N} s^2_{Apr\_vert,i} s^2_{i\_H1}$$ **Equation 3-57**

$$\sigma^2_{Apr\_lat\_H1} = \sum_{i=1}^{N} s^2_{Apr\_lat,i}\,\sigma^2_{i\_H1}$$ **Equation 3-58**

3.2.2.3.10.5.2.1.4 Vertical and Lateral Ephemeris Error Position Bounds

If the ephemeris error missed detection parameters are provided in the Type 2 message being used, then the PAN equipment shall compute the Vertical and Lateral Ephemeris Error Position Bounds for each ground station Type 1 message used in the navigation solution, relative to the selected approach segment (VPB_{Apr_e} and LPB_{Apr_e}).

The Vertical and Lateral Ephemeris Error Position bounds are given by:

$$VPB_{Apr\_e} = \max\left(VPB_{Apr\_e}[k]\right)$$ **Equation 3-59**

$$LPB_{Apr\_e} = \max\left(LPB_{Apr\_e}[k]\right)$$ **Equation 3-60**

Where:

$VPB_{Apr\_e}[k]$ is the vertical ephemeris error position bound relative to the selected approach segment for the k_{th} GPS ranging source used in the position solution, where $VPB_{Apr\_e}[k]$ is computed for all GPS ranging sources used in the position solution:

$$VPB_{Apr\_e}[k] = \left|s_{Apr\_vert,k}\right| x_{air} P_k + K_{md\_e\_CAT1}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_vert,i}\,\sigma_i^2}$$ **Equation 3-61**

P_k ≡ reference section 3.2.2.3.9.2

$s_{Apr\_vert,i}$ ≡ reference section 3.2.2.3.10.5.2.1.3

x_{air} ≡ reference section 3.2.2.3.9.2

σ_i ≡ weightings used in the least squares solution (reference section 3.2.2.3.8)

$K_{md\_e\_CAT1}$ = the broadcast multiplier for computation of the ephemeris error position bound for Category I precision approach derived from the probability of missed detection given that there is an ephemeris error in a GPS satellite (unit less)

$LPB_{Apr\_e}[k]$ is the lateral ephemeris error position bound relative to the selected approach segment for the kth GPS ranging source used in the position solution, where $LPB_{Apr\_e}[k]$ is computed for all GPS ranging sources used in the position solution:

$$LPB_{Apr\_e}[k] = \left|s_{Apr\_lat,k}\right| x_{air} P_k + K_{md\_e\_CAT1}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_lat,i}\,\sigma_i^2}$$ **Equation 3-62**

$s_{Apr\_lat,i}$ ≡ reference section 3.2.2.3.10.5.2.1.3

Note: *The ephemeris error position bounds are computed only for GPS satellites used in the position solution (k index) and not for other types of ranging sources (SBAS satellites or pseudolites) that are not subject to undetected ephemeris failures. However, the calculations of these position bounds use information from all ranging sources used in the position solution (i index).*

3.2.2.3.10.5.2.2 Bias Approach Monitor

The PAN shall perform the Bias Approach Monitor (BAM) evaluations when:

a. The computed position transitions from outside the PAR to inside the PAR, or once before outputting valid deviation if the approach is selected while the aircraft is inside the PAR; and,
b. Inside the PAR, if there is a change in the satellites that are used in the position solution (i.e., loss of a satellite or addition of a satellite).

The BAM evaluations are:

$$2\sqrt{\sum_{i=1}^{N} s_{Apr\_vert,i}^{2} s_{i}^{2}} \leq FASVAL \text{, and} \qquad \textbf{Equation 3-63}$$

$$|B_{j,Apr\_vert}| \leq \text{FASVAL for all j} \qquad \textbf{Equation 3-64}$$

The elements of s and B are as defined in section 3.2.2.3.10.5.2.1.3. The value of σ_i is as defined in section 3.2.2.3.8, with the exception that the value for $\sigma_{noise}[i]$ and $\sigma_{divg}[i]$ (reference section 3.2.2.3.11.1) can be based on the expected value after the pseudorange smoothing filter has reached steady state.

The vertical deviations shall be indicated as invalid if either of the BAM evaluations fail.

Note: *This monitor ensures that the projection of the FAS path realized in the airborne equipment passes within a window defined by the FASVAL, with high confidence. A lateral check is not required, as the vertical check is more stringent and provides sufficient screening.*

3.2.2.3.10.5.3 Distance to Threshold

The distance to threshold, defined as the horizontal distance between the aircraft position and the LTP/FTP, shall be computed from dynamically independent position updates.

3.2.2.3.10.5.3.1 Distance to Threshold Output

The PAN shall output the distance to threshold at a rate of at least once per second whenever the equipment is outputting valid lateral deviations.

Note: *The equipment may optionally output two aural indications that may be used by the pilot to cross check the altitude at given points along the approach.*

3.2.2.3.10.5.3.2 Distance to Threshold Latency

The distance to threshold output latency, defined as from when the distance is applicable until when the distance is output, shall not exceed 400 msec.

3.2.2.3.11 Error Models

3.2.2.3.11.1 Model of Airborne Pseudorange Performance

The s_{pr_air} shall be computed as follows:

$$s_{pr\_air}[i] = \left(s^2_{noise}[i] + s^2_{multipath}[i] + s^2_{divg}[i]\right)^{1/2}$$ **Equation 3-65**

The installed multi-path error for the airborne PAN equipment is described by the distribution,

$$N\left(0, s^2_{multipath}\right)$$ **Equation 3-66**

Where:

$$s_{multipath}[i] = 0.13 + 0.53e^{(-q[i]/10\deg)} \text{ (in meters)}$$ **Equation 3-67**

$q[i] =$ elevation angle of satellite *i* (in degrees)

$s_{divg}[i]$ (in meters) shall be greater than or equal to the differentially-corrected pseudorange error induced by the initialization, re-initialization, and steady-state effects of the airborne smoothing filter relative to the steady-state response of the filter defined in section 3.2.2.3.5.5, given code-carrier divergence that is defined to have a constant rate of 0.018 m/s.

Note 1: *A constant ionospheric divergence rate of 0.018 m/sec induces a steady-state bias of 1.8 m (0.018*100 sec smoothing time constant) in the broadcast differential correction. This bias produces a 1.8 meter error in the differentially-corrected pseudorange when the airborne smoothing filter is initialized or re-initialized. The initial 1.8 meter error decays with time as an equivalent bias is induced in the airborne smoothed pseudorange. If the smoothing algorithm defined in section 3.2.2.3.5.5 is used, this term will become negligible within 360 seconds after initialization of the smoothing filter. However, if the airborne smoothing filter converges to a different steady-state bias than the ground equipment, a steady-state error will remain which must be accounted for in* s_{divg}.

$\sigma_{noise}[i]$ (in meters) shall be the standard deviation of a normal distribution that bounds the errors in the tails of the distribution associated with the GNSS Receiver for satellite *i*, including receiver noise, thermal noise, interference, inter-channel biases, extrapolation, time since smoothing filter initialization, and processing errors.

The parameter σ_{noise} must change to reflect current signal conditions. For example, degradation to system accuracy due to interference must be accounted for in the value of σ_{pr_air} that is used in the protection level computations, within the time to alert.

Note 2: *The test procedures of RTCA/DO-253A [24] section 2.5.3.2 are sufficient to show compliance with both the accuracy requirement in section 3.2.2.3.5.7 and the* s_{noise} *requirement for integrity. The* s_{noise} *validated through those tests can be used as the standard deviation of a normal distribution that bounds the tails of the error distribution associated with the receiver tracking performance.*

The steady-state value of $\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2}$ at the minimum and maximum signal levels (section 3.2.2.3.5.2) shall be as follows:

GPS Satellites Minimum signal level:

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2}$ ≤? 0.36 meters for airborne Accuracy Designator A, and

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2} \leq$ 0.15 meters for airborne Accuracy Designator B

GPS Satellites, Maximum signal level:

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2} \leq$ 0.15 meters for airborne Accuracy Designator A, and

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2} \leq$ 0.11 meters for airborne Accuracy Designator B

SBAS Satellites, Minimum signal level:

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2} \leq 1.8$

SBAS Satellites, Maximum signal level:

$\left(s^{2}_{noise}[i]+s^{2}_{divg}[i]\right)^{1/2} \leq 1.0$

Note 3: *These inequalities are consistent with the accuracy requirement defined in section 3.2.2.3.5.7.*

Note 4: *These error models are valid for Civil Mode (C/A) and need to be defined for Military Mode (P(Y)).*

Note 5: *The Accuracy Designators are upper limits and actual receiver values should be implemented.*

3.2.2.3.11.2 Model of Tropospheric Residual Uncertainty

The residual tropospheric uncertainty (σ^2_{tropo}) (reference section 3.2.2.3.7.3) shall be defined as:

$$s_{tropo} = s_N h_0 \frac{10^{-6}}{\sqrt{0.002\sin^2(q)}}\left(1-e^{-\Delta h/h_0}\right) \qquad \textbf{Equation 3-68}$$

Where:

σ_N = refractivity uncertainty transmitted by ground subsystem in ground station message Type 2,

θ, Δh, and h_0 are defined in section 3.2.2.3.7.3.

3.2.2.3.11.3 Model of Ionospheric Residual Uncertainty

The residual ionospheric uncertainty shall be defined as:

$$\sigma_{iono} = F_{PP} \times \sigma_{vert\_iono\_gradient} \times \left(x_{air} + 2 \times \tau \times \nu_{air} \right) \qquad \textbf{Equation 3-69}$$

Where:

F_{PP} = the vertical-to-slant obliquity factor (unit less) for the given satellite and

$$F_{pp} = \left[1 - \left(\frac{R_e \cos\theta}{R_e + h_I} \right)^2 \right]^{-\frac{1}{2}} \qquad \textbf{Equation 3-70}$$

R_e = radius of the earth = 6378.1363 km

h_I = ionospheric shell height = 350 km

θ = the elevation angle of satellite

$\sigma_{vert\_iono\_gradient}$ = the standard deviation of a normal distribution associated with the residual ionospheric uncertainty due to spatial decorrelation (a parameter provided by the ground subsystem in Message Type 2)

$x_{air} \equiv$ reference section 3.2.2.3.9.2

τ = 100 seconds, the time constant of the smoothing filter in section 3.2.2.3.5.5

ν_{air} = the horizontal speed of the aircraft (meters/sec).

Note 1: *The "x_{air}" and "$2\tau\nu_{air}$" terms inside the equation for sigma_iono are the result of different ionospheric effects. The "x_{air}" term represents the difference in ionospheric slant delay between GBAS reference point and aircraft pierce points, given that the direction of the ionospheric spatial gradient is parallel to the vector between the GBAS reference point and aircraft. The "$2\tau\nu_{air}$" term represents the code-carrier divergence due to the ionospheric divergence that occurs when the aircraft traverses the ionosphere gradient over one smoothing time constant "τ." (The factor of 2 is due to the gradient impacting pseudorange and carrier phase measurements in opposite directions.) This term assumes that the direction of the ionosphere gradient is parallel to that of the aircraft motion over the last smoothing time constant. When the aircraft is moving directly toward the GBAS reference point, these two assumed gradient directions line up, and the computed σ_{iono} is a consistent bound. When the aircraft is not moving directly toward the GBAS reference point, the computed σ_{iono} is conservative because two different worst-case assumptions about the direction of the gradient are assumed at the same time. However, since the true direction of the gradient is unknown, the use of this conservative bound is appropriate in all cases.*

Note 2: *A method of divergence free carrier smoothing may be defined for dual frequency and/or single frequency GNSS receivers.*

3.2.2.4 GNSS Antenna Subsystem

3.2.2.4.1 GNSS Antenna

This section will provide performance requirements for GNSS antennas (e.g. MSO-C144 [13]).

3.2.2.4.2 Antenna Electronics

This section will provide performance requirements for antenna electronics (attitude input if required).

3.2.2.4.2.1 AJ

This section will provide MAS anti-jam (AJ) performance requirements.

3.2.2.5 Inertial Navigation System

Note: *Performance requirements for an inertial navigation system e.g. inertial aiding may be defined.*

3.2.2.6 LAAS CAT I Interoperability

MAS equipment shall interoperate with equipment meeting the civil requirements for LAAS category I, II and IIIa landings in effect at the time of certification.

Note: The requirements in effect as of time of preparation of this document are contained in TSO-C161 [31], and TSO-C162 [32].

3.2.3 Physical Characteristics

Specifies the requirements for physical characteristics (for example, weight limits, dimensional limits).

3.2.3.1 Power

JPALS MAS shall operate on existing aircraft power in accordance with aircraft platform equipment requirements without impacting aircraft bus capacity and shall not adversely impact aircraft requiring low observable performance.

MAS power consumption requirements shall not exceed current aircraft platform equipment.

3.2.3.1.1 Auxiliary Battery Power

The MAS shall provide auxiliary battery power to support GPS critical memory, selective availability/anti-spoofing (SA/A-S) cold load, and to maintain a resident time standard.

Battery life shall be a minimum of one year.

The battery shall be available from Military Stock.

The battery shall be housed within the dimensional limits of the MAS chassis or mounting tray.

Batteries shall be easily accessible so they may be removed for separate storage and for testing, replacement, and recharging.

3.2.3.2 Size and Weight

The size and weight of the MAS shall not exceed the requirements of the aircraft platform system.

3.2.3.3 Environmental Conditions and Electromagnetic Effects

The MAS shall meet all the performance requirements cited within this document while subject to the environmental conditions and electromagnetic effects as specified for the aircraft platform equipment.

The MAS shall meet any individual or combination of natural and induced environmental conditions as specified for the aircraft platform equipment without mechanical or electrical damage or operational degradation.

3.2.3.3.1 TEMPEST

The installation of MAS equipment onto a platform shall not adversely affect the TEMPEST characteristics of the platform.

3.2.4 Reliability

The MAS shall meet all the reliability requirements as specified for the aircraft platform equipment.

3.2.5 Maintainability

The MAS shall meet all the maintainability requirements as specified for the aircraft platform equipment.

3.2.6 Environment, Safety and Health

The MAS shall meet all the environment, safety and health requirements as specified for the aircraft platform equipment.

3.2.7 Transportability

The MAS shall meet all the transportation and materials handling requirements as specified for the aircraft platform equipment.

3.2.8 Flexibility

The MAS shall meet all the system flexibility and expansion requirements as specified for the aircraft platform equipment.

3.2.9 Operational Command and Control Requirements

The MAS shall accept mode and sub-mode (see 3.1.2) control via an open architecture interface.

The MAS shall accept channel selection (see 3.1.2.1.1.1 and 3.1.2.1.1.2) via an open architecture interface.

3.3 Design and Construction Requirements

This section specifies the minimum system design and construction standards that have general applicability to system equipment. These design and construction standards are applicable to major classes of equipment or to particular design standards. To the maximum extent possible, these requirements are specified by the incorporation of established standards and specifications. Requirements that add to but do not conflict with requirements specified are included in individual CI specifications.

3.3.1 Materials, Processes, and Parts

The MAS shall meet all the peculiar requirements of the system that govern the use of materials, parts and processes in the design of system equipment as specified for the aircraft platform equipment.

3.3.1.1 Product Marking

The MAS shall meet all the identifying marking requirements as specified for the aircraft platform equipment.

3.3.1.2 Interchangeability/ Modularity

The MAS shall meet all interchangeable and replaceable system equipment requirements as specified for the aircraft platform equipment.

3.3.2 Safety Engineering

The MAS shall meet all safety requirements as specified for the aircraft platform equipment.

3.3.3 Human Engineering

The MAS shall meet all human engineering requirements as specified for the aircraft platform equipment.

3.3.4 Software

All MAS software designs shall consider the guidelines and objectives of the applicable software level specified in RTCA/DO-178B [17].

The MAS shall meet all software requirements as specified for the aircraft platform equipment.

3.3.5 Hardware

All MAS electronic hardware designs shall consider the guidelines and objectives of the applicable hardware design assurance level specified in RTCA/DO-254 [25].

3.3.5.1 Computer Resource Reserve Requirements

The MAS shall meet all computer resource reserve capacity (i.e. memory, timing) requirements as specified for the aircraft platform equipment.

3.3.6 Existing/Pre-Defined Property Usage

The MAS shall meet requirements for existing equipment and software to be incorporated into the system as specified for the aircraft platform equipment.

3.3.7 System Security

The MAS shall comply with the JPALS Security Classification Guide [11].

The MAS shall comply with the GPS System Protection Guide [14].

The MAS shall comply with the system security requirements specified for the aircraft platform equipment.

3.3.8 Military Self-Certification

The platform integrator shall determine if the certification requirements of the MAS are adequate for the aircraft certification.

Civil certified platform integrators shall verify the MAS equipment does not interfere with the operation of civil certified equipment.

3.4 Logistics Requirements

The MAS shall meet all logistics requirements as specified for the aircraft platform equipment.

3.5 Personnel and Training Requirements

The MAS shall meet all personnel and training requirements as specified for the aircraft platform equipment.

4 Quality Assurance and Verification Requirements

This section describes the level of testing that the MAS shall be subjected to in order to verify compliance with the baseline functional, performance and interface requirements of this specification. These tests shall be conducted with the MAS as a stand-alone unit, but with the intent of assuring that the MAS will meet the level of baseline performance stated in this specification when integrated into the aircraft platform. Compliance with the baseline requirements of this specification shall be verified by analysis, inspection, demonstration, test, or a combination thereof as defined below. A cross reference of requirements to the verification method is provided in Table 4-1.

4.1 Responsibilities (Verification Strategy)

This section identifies the assignment of the responsibility to perform inspections on delivered products, materials, or services to determine compliance with all specified requirements.

4.1.1 Special Tests and Examinations

This section identifies the special tests and examinations required for sampling, qualification evaluation, or other tests or examinations, as necessary.

4.2 Verification Methods

4.2.1 Inspection

Inspection (I)—Inspection is defined as a visual verification that the equipment as manufactured conforms to the requirements documentation to which it was designed.

4.2.2 Analysis

Analysis (A)—Analysis is defined as the verification that a specified requirement has been met through the technical evaluation of equations, charts, reduced data and/or representation data.

4.2.3 Demonstration

Demonstration (D)—Demonstration is defined as a non-instrumented test where success is determined by observation alone. Included in this category are tests that require simple quantitative measurements such as dimensions, time to perform tasks, etc.

4.2.4 Test

Test (T)—Test is defined as the verification that a specified requirement is met by a thorough exercising of the applicable element under appropriate conditions and using appropriate instrumentation in accordance with test procedures.

4.2.5 Qualification by Similarity

A qualification by similarity is a prediction based on existing data with detailed examination of the differences and similarities between the previously qualified item and the item under consideration. The contractor may propose this method for use to the Government on a case by case basis.

4.3 Requirements Traceability Table

Table 4-1 Verification Matrix

Standard Requirements		***Verification Method***				
Paragraph	***Paragraph Title***	***I***	***A***	***D***	***T***	***Notes***
	Note: Verification Matrix is TBD.					

5 Packaging and Preparation for Delivery

The MAS shall meet the requirements for delivery, including packaging and handling as specified for the aircraft platform equipment.

Appendix A TERMS and ACRONYMS

This section defines the terms, acronyms, and abbreviations as used in this document.

A.1 Terms

The following terms are used throughout this document to express the degree of obligation of a requirement: “Shall” or “must” means the requirement/attribute is mandatory. “Should” means the requirement/attribute is recommended. “Will” indicates futurity and does not indicate any degree of obligation or requirement.

Table A-1 provides definitions of specific technical terms as used in this specification:

Table A-1 Technical Terms

TERM	***DEFINITION***
abnormal maneuvers	Abnormal maneuvers are defined to be maneuvers having accelerations/jerks that exceed those specified in 3.2.2.3.2.
H0 hypothesis	The H0 hypothesis assumes the situation where no faults are present in the range measurements (includes both the signal and the receiver measurements) used in the ground station to compute the differential corrections.
H1 hypothesis	The H1 hypothesis assumes the situation when a fault is present in one or more range measurements and is caused by one of the reference receivers used in the ground station.
Line Replaceable Unit (LRU)	An item that is normally removed and replaced as a single unit to correct a deficiency or malfunction on a weapon or support system. Such items have a distinctive stock number for which spares are locally authorized to support the removal and replacement action. These items are repair cycle assets subject to “due in from maintenance” controls (Technical Order 00-20-3) and may be disassembled into separate components during shop processing.
LAAS	A generic reference to GBAS as defined by ICAO, as the requirements in this standard are intended to comply with the ICAO Standards and Recommended Practices (SARPs) [27] for the GBAS aircraft element.
Message Failure Rate (MFR)	The MFR is defined as the total number of messages lost by the VDB receiver subsystem plus those messages which do not pass the CRC divided by the total number of messages sent by the ground subsystem.
Mean Time Between Failure (MTBF)	The duration of probability of failure-free performance when in an operational environment. MTBF is based on any downing event or failure which degrades system performance while in an operational environment.
normal maneuvers	Normal maneuvers are defined to be maneuvers having accelerations/jerks that are within those specified in 3.2.2.3.2.
open architecture	An architecture whose specifications are public. This includes officially approved standards as well as privately designed architectures whose specifications are made public by the designers.
Scheduled Maintenance	A series of planned inspection, detection, service and/or hardware replacement actions performed at a prescribed point in the item’s life in an attempt to retain it in a specified condition and prevent an unacceptable condition from occurring.

A.2 Acronyms

Table A-2 shows the abbreviations, acronyms, and mnemonics used in this document:

Table A-2 Abbreviations, Acronyms and Mnemonics

ITEM	***MEANING***
AFC	automatic frequency control
AFB	Air Force Base
AJ	anti-jam
BAM	Bias Approach Monitor
BIT	built-in-test
BW	bandwidth
C/A	GPS Coarse/Acquisition Code available to all users
CAT I	Category I (one)
CAT II	Category II (two)
CAT IIIa	Category IIIa (three a)
CFR	Code of Federal Regulations
CDRL	Contract Data Requirements List
C/No	carrier-to-noise power ratio
CRAF	Civil Reserve Air Fleet
CRC	cyclic redundancy check
CW	continuous wave
dB	decibel
dBm	decibel referenced to 1 milliwatt
DD	double delta (discriminator)
DDM	difference in depth of modulation (ILS)
Δ	delta
DLL	delay lock loop
DoD	Department of Defense
E-L	early-minus-late (discriminator)
FAA	Federal Aviation Administration
FAS	Final Approach Segment
FASLAL	Final Approach Segment Lateral Alert Limit
FASVAL	Final Approach Segment Vertical Alert Limit
FM	frequency modulation
FPAP	flight path alignment point
FSD	full-scale deflection
ft	foot
FTP	fictitious threshold point
g	gravitational acceleration
g/s	gravitational acceleration per second
GARP	GLS azimuth reference point
GBAS	Ground Based Augmentation System
GCID	Ground Continuity Integrity Designator
GERP	GLS elevation reference point
GPA	glide path angle
GPS	Global Positioning System
GLS	GNSS Landing System
GPIP	glide path intercept point
GNSS	Global Navigation Satellite System
GRAM	GPS Receiver Application Module
GRP	guidance reference point
HAE	host application equipment
HFOM	horizontal figure of merit
HPL	Horizontal Protection Level
Hz	Hertz
ICAO	International Civil Aviation Organization

ITEM	MEANING
ICD	Interface Control Document
ID	identification
ILS	Instrument Landing System
IOD	issue of data
IODC	issue of data clock
IODE	issue of data ephemeris
INS	Inertial Navigation Sensor
IRS	Inertial Reference System
JPALS	Joint Precision Approach and Landing System
kHz	kilo-Hertz
kts	knots (nautical miles per hour)
L1	GPS L-band signal and/or frequency at 1575.42 MHz
L2	GPS L-band signal and/or frequency at 1227.60 MHz
L5	GPS L-band signal and/or frequency at 1176.45 MHz
LAAS	Local Area Augmentation System
LDGPS	Local Area Differential Global Positioning System
LGF	LAAS Ground Facility
LRU	Line Replacement Unit
LTP	Landing Threshold Point
m	meter
μA	micro-amperes
mA	milli-amperes
MASPS	Minimum Aviation System Performance Standards
MAS	Military Airborne Segment
M-Code	GPS Military Code available only to authorized users
MBI	Message Block Identifier
MFR	Message Failure Rate
MGS	Military Ground Segment
MHz	Mega-Hertz
MLS	Microwave Landing System
mod	modulus (remainder of division process)
MOPS	Minimum Operational Performance Standards
MPNTP	Master Positioning Navigation and Timing Plan
m/s	meters per second
MSO	Military Standard Order
MTBF	mean time between failure
ORD	Operational Requirements Document
PAN	Precision Approach Navigator
PAR	Precision Approach Region
POST	power-on-self-test
P(Y)	GPS Precise Code available only to authorized users
ppm	parts per million
PPS	Precise Positioning Service
PVT	Position, Velocity and Time
RF	Radio Frequency
RMS	root-mean-squared
RNAV	Area Navigation
RPDS	Reference Path Data Selector
SA	selective availability
SA/A-S	Selective Availability/Anti-Spoofing
SAASM	Selective Availability and Anti-Spoofing Module
SARPs	Standards and Recommended Practices

ITEM	MEANING
SBAS	Satellite Based Augmentation System
SIS	Signal In Space
SPS	Standard Positioning Service
SRD	System Requirements Document
SL 7	JPALS guidance quality Service Level 7
SL 8	JPALS guidance quality Service Level 8
SL 9	JPALS guidance quality Service Level 9
TBD	to be determined
TCH	threshold crossing height
TEMPEST	Unclassified US government code word for compromising emanations; now called Emissions Security or EMSEC
TSO	FAA Technical Standard Order
UHF	Ultra High Frequency
US	United States (of America)
UTC	coordinated universal time
VDB	VHF Data Broadcast
VFOM	Vertical figure of merit
VHF	Very High Frequency
VOR	VHF Omni-directional Range
VPL	Vertical Protection Level
VSWR	Voltage Standing Wave Ratio
WGS-84	World Geodetic System 1984

Appendix B Vulnerability Requirements

Appendix C RTCA/DO-253A [24] Compliance Matrix

MOPS Para.	MAS Standard Para.	Title	Compliance	Comment
2.2	3.2.1.2	VDB Receiver Subsystem	Information	
2.2.1	3.2.1.2.1	General	Required	
2.2.1.1	3.2.1.2.1.1	Design Assurance	Required	
2.2.1.1.1	3.2.1.2.1.1.1	Hardware	Required	
2.2.1.1.2	3.2.1.2.1.1.2	Software	Required	
2.2.2	3.2.1.2.2.	Tuning	Information	
2.2.2.1	3.2.1.2.2.1	Frequency Range	Required	
2.2.2.2	3.2.1.2.2.2	Frequency Selection	Required	
2.2.2.3	3.2.1.2.2.3	Response Time	Required	
2.2.3	3.2.1.2.3	Data Latency	Required	
2.2.4	3.2.1.2.4	Data Format Decoding	Required	
2.2.5	3.2.1.2.5	Message Failure Rate	Required	
2.2.6	3.2.1.2.6	VDB Signal Tracking Requirements	Information	
2.2.6.1	3.2.1.2.6.1	Sensitivity and Dynamic Range	Required	
2.2.6.2	3.2.1.2.6.2	Carrier Frequency Capture Range	Required	
2.2.6.3	3.2.1.2.6.3	Carrier Frequency Slew Rate	Required	
2.2.6.4	3.2.1.2.6.4	Symbol Rate Tolerance	Required	
2.2.6.5	3.2.1.2.6.5	Slot-To-Slot Variations Within a Given Frame	Required	
2.2.6.6	3.2.1.2.6.6	Frame-to-Frame Variations for a Given Slot	Required	
2.2.7	3.2.1.2.7	Co-Channel Rejection	Information	
2.2.7.1	3.2.1.2.7.1	VDB as the Undesired Signal	Required	Corrected incorrect reference in MOPS
2.2.7.2	3.2.1.2.7.2	VOR as the Undesired	Required	Corrected incorrect reference in MOPS

MOPS Para.	MAS Standard Para.	Title	Compliance	Comment
		Signal		
2.2.7.3	3.2.1.2.7.3	ILS Localizer as the Undesired Signal	Required	Corrected incorrect reference in MOPS
2.2.8	3.2.1.2.8	Adjacent Channel Rejection	Information	
2.2.8.1	3.2.1.2.8.1	1st Adjacent 25 kHz Channels	Required	
2.2.8.2	3.2.1.2.8.2	2nd Adjacent 25 kHz Channels	Required	
2.2.8.3	3.2.1.2.8.3	3rd Adjacent 25 kHz Channels	Required	
2.2.9	3.2.1.2.9	Out-of-Band Rejection	Information	
2.2.9.1	3.2.1.2.9.1	Desensitization	Required	
2.2.9.2	3.2.1.2.9.2	FM Broadcast Band Intermodulation Rejection	Required	
2.2.9.3	3.2.1.2.9.3	Burn Out Protection	Required	
2.2.10	3.2.1.2.10	Receiver-to-Antenna Interface	Information	
2.2.10.1	3.2.1.2.10.1	Receiver Voltage Standing Wave Ratio (VSWR)	Required	
2.2.10.2	3.2.1.2.10.2	Antenna Characteristics	Required	
2.2.10.2.1	3.2.1.2.10.2.1	Horizontally Polarized Antenna Characteristics	Information	
2.2.10.2.1.1	3.2.1.2.10.2.1.1	Horizontal Antenna Gain	Required	
2.2.10.2.1.2	3.2.1.2.10.2.1.2	Horizontal Antenna VSWR	Required	
2.2.10.2.2	3.2.1.2.10.2.2	Vertically Polarized Antenna Characteristics	Information	
2.2.10.2.2.1	3.2.1.2.10.2.2.1	Vertical Antenna Gain	Required	
2.2.10.2.2.2	3.2.1.2.10.2.2.2	Vertical Antenna VSWR	Required	
2.3	3.2.1.3	Precision Approach Navigator	Information	

MOPS Para.	***MAS Standard Para.***	***Title***	***Compliance***	***Comment***
2.3.1	3.2.1.3.1	General	Partial	Requirements for the JPALS MAS when not applying differential corrections are TBD.
2.3.2	3.2.1.3.2	Design Assurance	Required	
2.3.2.1	3.2.1.3.2.1	Hardware	Required	
2.3.2.2	3.2.1.3.2.2	Software	Required	
2.3.3	3.2.1.3.3.1	Interference and Dynamics Environment	Required	Definition of normal dynamics may be expanded to support military applications.
2.3.4	3.2.1.3.4.1	Approach Selection	Required	
2.3.5	3.2.1.3.4.2	Reference Path Data Selector (RPDS) and Frequency Mapping	Required	
2.3.6	---	GNSS Receiver Function	Information	
2.3.6.1	3.2.1.3.3.2	Ranging Sources	Required+	MAS required to support 12 ranging sources to support SL 8 requirements as well as L1 P(Y) and L2 P(Y).
2.3.6.2	3.2.1.3.3.5	Sensitivity and Dynamic Range	Required+	Power levels and background thermal noise specified for L1 P(Y) and L2 P(Y)
2.3.6.3	3.2.1.3.3.6	Equipment Burnout Protection	Required+	CW signal at either L1 or L2
2.3.6.4	3.2.1.3.3.7, 3.2.1.3.4.3.1	GPS Signal Processing	Required	
2.3.6.4.1	3.2.1.3.3.7.1	GPS Tracking Constraints	Required+	This requirement will be expanded to include P(Y) code.
2.3.6.4.2	3.2.1.3.3.7.2	Correlation Peak Validation	Required+	This requirement will be expanded to include P(Y) code.
2.3.6.4.3	3.2.1.3.3.7.3	GPS Satellite Acquisition Time	Required+	This requirement is superceded by the GRAM requirements.
2.3.6.4.4	3.2.1.3.3.7.3	GPS Satellite Reacquisition Time	Required+	This requirement is superceded by the GRAM requirements.
2.3.6.5	3.2.1.3.3.8, 3.2.1.3.4.3.2	SBAS Signal Processing	Required	

MOPS Para.	*MAS Standard Para.*	*Title*	*Compliance*	*Comment*
2.3.6.6	3.2.1.3.4.3.3	Smoothing	Required	
2.3.6.7	3.2.1.3.4.3.4	Measurement Quality Monitoring	Required	
2.3.6.8	3.2.1.3.3.10	Accuracy	Information	
2.3.6.8.1	3.2.1.3.3.10.1	GPS Satellites	Required+	MAS will support Accuracy Designator B for SL 8 operations. JPALS accuracy requirements are TBD.
2.3.6.8.2	3.2.1.3.3.10.2	SBAS Satellites	Required	Use of SBAS to support SL 8 is TBD.
2.3.6.9	3.2.1.3.4.3.5	Integrity in the Presence of Abnormal Interference	Required+	Integrity to be met in more stringent JPALS interference environment
2.3.6.10	3.2.1.3.4.3.6	Integrity in the Presence Abnormal Dynamics	Required	Definition of abnormal dynamics may be expanded to support military applications.
2.3.7	3.2.1.3.4.4	Message Processing Function	Required+	Additional message types must be supported for SL 8 and Military applications.
2.3.7.1	3.2.1.3.4.4.3	VDB Message Validity Check	Required	
2.3.7.2	3.2.1.3.4.4.4	VDB Message Block Identifier Check	Required+	Must support both “Civil” and “JPALS” message block identifier.
2.3.7.3	3.2.1.3.4.4.5	FAS Data Block Selection	Required	
2.3.7.4	3.2.1.3.4.4.6	Reference Station Selection	Required	
2.3.8	3.2.1.3.4.5	Precision Approach Region	Required	
2.3.9	3.2.1.3.4.6	Corrected Pseudorange	Information	
2.3.9.1	3.2.1.3.4.6.1	Conditions for Use of Differential Corrections	Information	
2.3.9.1.1	3.2.1.3.4.6.1.1	Ground Continuity Integrity Designator (GCID) Conditions	Required	
2.3.9.1.2	3.2.1.3.4.6.1.2	Ephemeris CRC Conditions	Required	
2.3.9.1.3	3.2.1.3.4.6.1.3	Reference Time Conditions	Required	

MOPS Para.	*MAS Standard Para.*	*Title*	*Compliance*	*Comment*
2.3.9.1.4	3.2.1.3.4.6.1.4	Other Ranging Source Conditions	Required+	Reduced elapsed time for SL 8 to support SL 8 time-to-alarm requirement
2.3.9.2	3.2.1.3.4.6.2	Application of Differential Corrections	Required	
2.3.9.3	3.2.1.3.4.6.3	Tropospheric Correction	Required	
2.3.10	3.2.1.3.4.7	LAAS Differential Positioning Requirements	Required+	JPALS requires a weighted least squares implementation.
2.3.11	3.2.1.3.4.8	Position Velocity and Time (PVT) Outputs	Required	
2.3.11.1	3.2.1.3.4.8.1	Protection Levels	Required	
2.3.11.2	3.2.1.3.4.8.2	Figure of Merit	Required	
2.3.11.3	3.2.1.3.4.8.3	PVT Output Latency	Required	
2.3.12	3.2.1.3.4.9	Deviations	Information	
2.3.12.1	3.2.1.3.4.9.1	Approach Status Verification	Required	
2.3.12.2	3.2.1.3.4.9.2	Deviation Outputs	Required	
2.3.12.3	3.2.1.3.4.9.3	Deviation Output Rate and Latency	Required	
2.3.12.4	3.2.1.3.4.9.4	Lateral Deviations for the Approach Segment	Information	
2.3.12.4.1	3.2.1.3.4.9.4.1	Proportional Lateral Deviation	Required	
2.3.12.4.2	3.2.1.3.4.9.4.2	Rectilinear Lateral Deviation	Required	
2.3.12.5	3.2.1.3.4.9.5	Vertical Deviations for the Approach Segment	Required	
2.3.12.5.1	3.2.1.3.4.9.5.1	Proportional Vertical Deviation	Required	
2.3.12.5.2	3.2.1.3.4.9.5.2	Rectilinear Vertical Deviation	Required	
2.3.12.6	3.2.1.3.4.9.6	Missed Approach	Required	

MOPS Para.	MAS Standard Para.	Title	Compliance	Comment
		Guidance		
2.3.13	3.2.1.3.4.10	Alerts	Information	
2.3.13.1	3.2.1.3.4.10.1	Loss of Approach Guidance	Required	
2.3.13.1.1	3.2.1.3.4.10.1.1	Alert Limits	Information	
2.3.13.1.1.1	3.2.1.3.4.10.1.1.1	Lateral Alert Limits	Required+	Alert Limits have been modified to reflect SL 8 performance requirements.
2.3.13.1.1.2	3.2.1.3.4.10.1.1.2	Vertical Alert Limits	Required+	Alert Limits will be modified to reflect SL 8 performance requirements.
2.3.13.1.2	3.2.1.3.4.10.1.2	Model of Airborne Accuracy	Required	
2.3.13.1.3	3.2.1.3.4.10.1.3	Model of Tropospheric Accuracy	Required	
2.3.13.1.4	3.2.1.3.4.10.1.4	Lateral and Vertical Protection Levels for Precision Approach	Required+	VPL and LPL computations have been modified to reflect SL 8 performance requirements
2.3.13.1.5	3.2.1.3.4.10.1.5	Horizontal and Vertical Protection Levels and Figures of Merit for PVT Outputs	Required	
2.3.13.2	3.2.1.3.4.10.2	Bias Approach Monitor	Required	
2.3.14	3.2.1.3.4.11	Distance to Threshold	Required	
2.3.14.1	3.2.1.3.4.11.1	Distance to Threshold Output	Required	
2.3.14.2	3.2.1.3.4.11.2	Distance to Threshold Output Latency	Required	

Appendix D Issues